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MINING OPERATIONS AT THE PROPERTY OF THE BRITANNIA MINING & SMELTING CO., LTD., BRITANNIA BEACH, BRITISH COLUMBIA

BY

C. V. BRENNAN

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MINING OPERATIONS AT THE PROPERTY OF THE BRITANNIA MINING & SMELTING CO., LTD., BRITANNIA BEACH, BRITISH COLUMBIA[1]

By C. V. Brennan[2]

INTRODUCTION

This paper, describing the various mining methods and practices at Britannia mines, Britannia Beach, British Columbia, is one of a series covering mining practices, methods, and costs in the mining districts of the United States and Canada.

The Britannia property has been operated continuously for 30 years, and in that time many diverse methods have been used in exploiting the various types of orebodies worked.

Under normal conditions mining methods include surface gloryholes, shrinkage stoping, shrinkage with powder drifts for primary breaking, horizontal cut-and-fill, horizontal and inclined square-setting, and timbered and open rills, the three latter systems being combined with close filling.

The Britannia method of mining, a large-scale retreating shrinkage system usually combined with powder drifts for primary breaking, has been developed and applied here very successfully.

Each block of ground as developed is studied as a separate problem, and the mining method or combination of methods best adapted to the work in hand is applied thereto. Operating at capacity, the series of mines produces 7,000 tons of ore per day.

ACKNOWLEDGMENTS

The author wishes to acknowledge the material assistance of C. G. Dobson and J. P. Lee, assistant mine superintendents; F. Ebbutt, mine geologist; H. E. Parsons, mechanical engineer; P. B. Everest, research engineer; N. D. Bothwell, safety engineer; and T. D. McClellan, mine accountant, in the preparation and illustration of this paper.

HISTORY

Britannia Beach is about 20 miles from Vancouver in a straight line or about 30 miles by water up Howe Sound, which was discovered and named by Captain George Vancouver. It is reported that the first copper was found in the area by Dr. Forbes in 1888. Ten years later Oliver Furry located five claims from which a large portion of the mine production has since come. Early in 1900 the Britannia Copper Syndicate was organized to work the property.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6815."

[2] One of the consulting engineers, U.S. Bureau of Mines, and assistant general manager, Britannia Mining & Smelting Co., Ltd.

About 1903 Grant B. Schley became interested in the affairs of the syndicate and was instrumental in furnishing the necessary capital for the development and construction that followed. A concentrator with a capacity of 200 tons per day was built, an aerial tramway was erected, and new adits were started. Ore and concentrates were shipped to the company's smelter at Crofton on Vancouver Island. The Britannia Mining & Smelting Co., Ltd., was incorporated in 1908 and is completely owned by Howe Sound Co. The smelter at Crofton was closed down in 1913 because of a lack of custom ore resulting in part from improved milling practice. During the years that followed the company augmented its holdings by the staking and purchase of a great many claims until it now owns approximately 25,000 acres extending eastward from the shores of Howe Sound to the Indian River Valley, a distance of over 10 miles. The company has expended large sums for plant and buildings which, with the cost of property added, represent an investment of over $10,000,000.

After the death of Grant B. Schley in 1917 his son, E. B. Schley, and W. J. Quigly became, respectively, chairman of the board and president of the Howe Sound Co. C. P. Browning is general manager of the Britannia Mining & Smelting Co., Ltd.

GEOLOGY

Physiography

The immediate vicinity of the Britannia mines is one of strong relief. The Coast Range Mountains rise steeply from tidewater to elevations of 6,000 feet or more. Generally, they are thickly wooded and show few outcrops, except at the higher elevations.

General Geology

The ore deposits occur in a roof pendant on the western flank of the Coast Range batholith, the outstanding feature of the geology of British Columbia. (See figs. 1 and 2.) The batholith is of a relatively composite nature, but is considered, broadly, late Jurassic. The roof pendant is a remnant of prebatholith volcanic and sedimentary formations laid down in the late Triassic or early Jurassic. This remnant of these older rocks is approximately 2 miles wide and 7 miles long. It comprises andesitic agglomerates, breccias, tuffs, and flows; rhyolitic volcanics and greywacke; and greenstones and black slates. Together, these make up the Britannia formation. Roughly, the rocks strike east and west, parallel to the long axis of the roof pendant. They were involved in mountain building before, during, and after the formation of the batholith. Only the remains of the major structure exist due to extensive erosion. Feldspar porphyry sills gained access to these roof pendant rocks just after the birth of the batholith. Small diorite and smaller lamprophyre dykes cut the older rocks at various places but have little significance economically, as they seldom affect mining and appear to have no direct bearing on ore deposition. A large, shear zone roughly follows the long axis of the roof pendant.

Physical Characteristics of Ore and Enclosing Rocks

The Britannia mines comprise several separate orebodies. These from west to east are the Jane, West Bluff, East Bluff, Fairview, Empress, and Victoria. The orebodies differ in character, although they are arranged along the general strike of the main shear zone. Most of them occur in conjunction with folds in the slate footwall, which dips south at an average of 65°, but there are local variation of as much as 25°. The folds plunge as much as 45° west (See fig. 21) whereas the easterly ones plunge only slightly. Their development was accom-

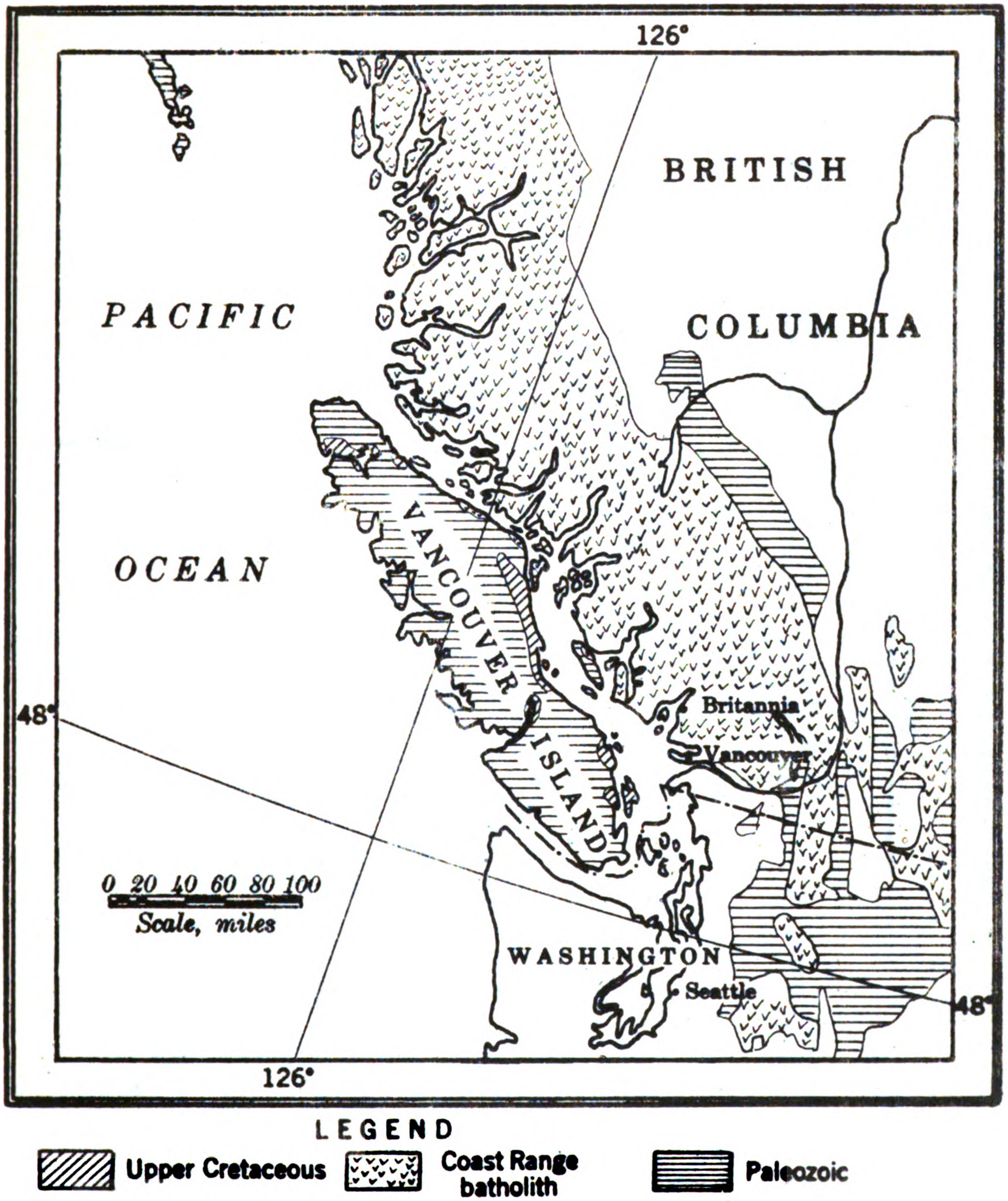


Figure 1.—Key map showing relation of Britannia to regional geology.

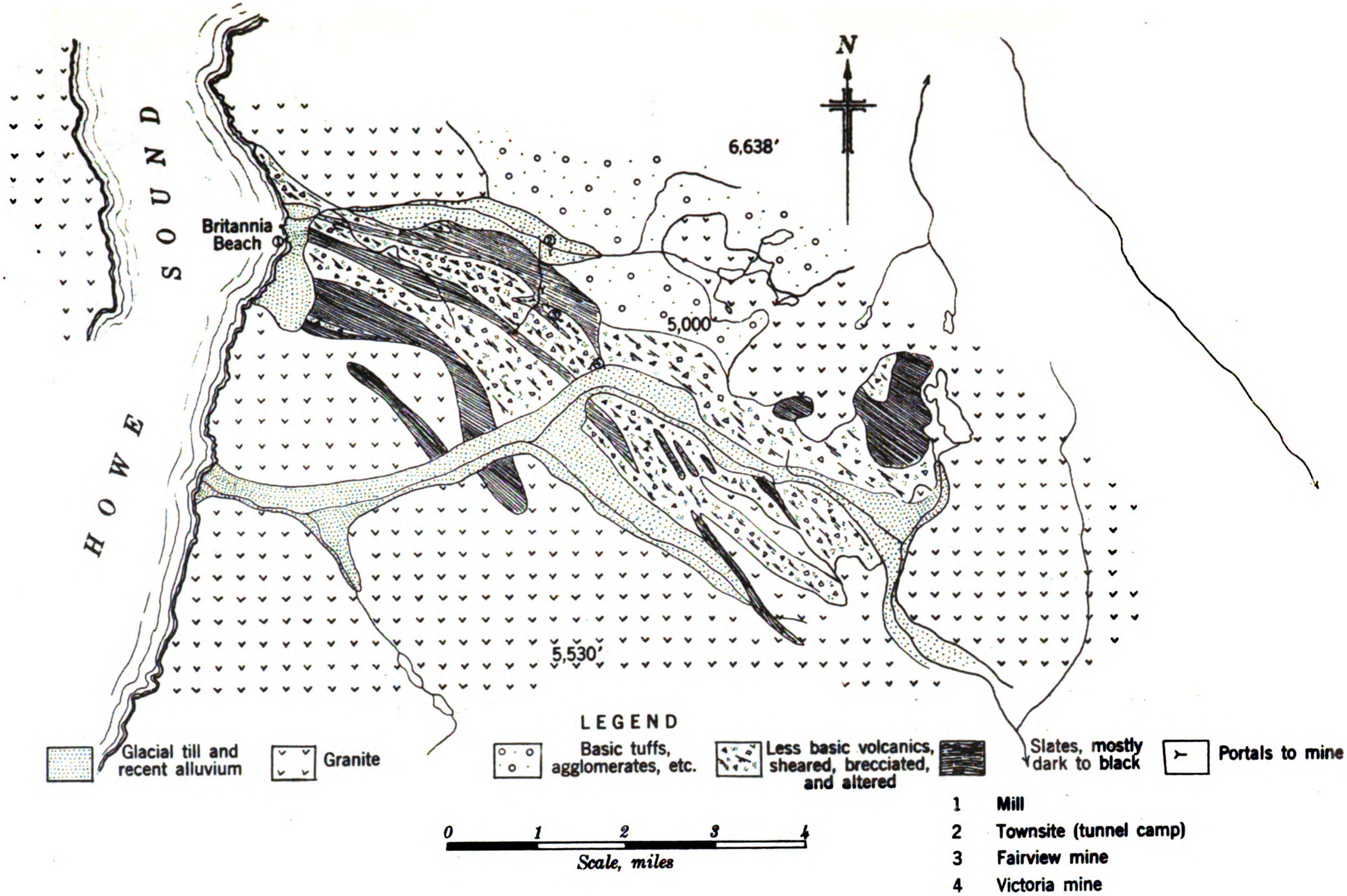


Figure 2.– Generalized geology of Britannia area.

panied by extensive local brecciation, fracturing, and fissuring of the relatively competent volcanic rocks. The incompetent slates and tuffs of the footwall formed a good lubricant and greatly facilitated the adjustments that resulted in brecciation, fracturing, and fissuring, thus making excellent hosts for ore deposition. Much shearing took place, but the schistose sections did not make good hosts and are only slightly mineralized or entirely barren, depending largely on the amount of shearing; the more fissile the schists the less the mineralization.

Locally, these folds show marked chertification, replacement, and silicification especially in all the western ore horizons except the Jane. Here the footwall slates and tuffs are replaced by disseminated sulphides and a little quartz. Quartz occurs only sparingly in the Victoria deposit, whereas in the East and West Bluff deposits it is predominant and of several generations. Each of these several stages of mineralization followed brecciation or fracturing of the previous stage or the original brecciation of the volcanics. The cherty stage was always first, followed by intensive adjacent silicification and replacement of the broken volcanics, with some pyritization. Further adjustments admitted more quartz, accompanied by further replacement and mineralization by pyrite, chalcopyrite, and sphalerite. This was the most important stage of mineralization. A later stage of quartz was accompanied by a little galena, and another stage, the last, is represented by only minor quartz stringers carrying some pyrite and minor gold values.

Owing to the extensive silicification in the East and West Bluff deposits, even in spite of the great widths (up to 200 feet) mining can be carried on without the use of any support; on the other hand, the wall rocks of the more veinlike orebodies of the Fairview deposit are such that shrinkage stoping is practised. In the Victoria deposit, which is made up of fissure veins, massive chalcopyrite, and little quartz, square-setting with close filling is required, as the walls are slabby and weak.

The chalcopyrite is the most important mineral, but pyrite and sphalerite are also saved in the mill. The gold and small amounts of silver are recovered with the concentrates.

METHODS OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

Sampling

The sampling crew comprises 2 to 4 men. In development work a chip sample is taken with a sampling pick from every round blasted. In stopes a breast sample of every blast is similarly taken. The samplers sketch the detail of ground broken in stopes as they make their rounds, using the surveyor's current contour maps, which are made up monthly. An up-to-date and fairly accurate stope map is thus available at all times between surveys.

At the end of each month the samplers make up assay maps on the basis of the surveyor's new contour map, and white prints of these are given to the foremen interested.

A special sampler is often employed on nonroutine work, such as resampling old drifts or the special sampling of bulldoze chambers. The latter is very important work and is necessary when a finished stope has been drawn down to a point at which dilution begins to approach the economic limit.

The sampler takes several shovelfuls of muck at intervals over a period of 2 hours; the sample is then quartered down to about 50 pounds and sent to the assay office. At the end of the shift the special sampler makes a written report to the mine geologist; this includes notes on the type of muck, speed of drawing, and other points of interest.

Ore Reserves

Ore reserves are set up annually in four classes - broken, positive, probable, and possible.

Broken Reserves.- Broken reserves are based on the tonnages calculated by the surveyor's monthly measurements taken when the stopes are surveyed. Contour intervals of 10 feet are used, and the areas are planimetered and volumes calculated. The grade is based on the composite of all assays taken in the course of mining the block from the sampler's stope assay plans. Owing to dilution from the hanging wall, the grade of ore drawn sometimes does not equal the grade set up in the ore-reserve sheet, but as the tonnage drawn is usually larger than that estimated the total mineral production exceeds the calculated figure. The tonnage factor is 11 cubic feet of ore in place.

Positive Reserves.- Positive reserves include only ore thoroughly blocked out by development and diamond-drilling. Calculations are then based on all the available information, and a safety factor of 10 to 20 percent is introduced to cover losses incidental tM mining and the possibility of included low-grade portions.

Probable Reserves.- Probable reserves are those not sufficiently developed to be included in the positive class but have excellent expectancy.

Possible Reserves.- Possible reserves comprise inaccessible areas on which information cannot be checked at this time but which, in the combined judgment of the superintendent, engineer, and geologist, are known to exist. Less than 2 percent of the total ore estimate comes under this classification.

Grouped assay plans are kept for all levels; these are used in conjunction with the geological plans and sections and the assay-record book to compute ore reserves. Tonnage sections are kept for each section of the mine, one sheet for each vein or separate orebody. On these tonnage sections each ore-reserve block is designated by letters according to class.

The system enables one to see quickly in which category any block belongs. Tabulations of tonnages, assay values, and dimensions of blocks are carried on the margin of each sheet. Areas mined out are colored each year so that the production shows clearly. These tonnage-reserve sections are drawn on a scale of 40 or 80 feet to the inch, according to the size of the orebody.

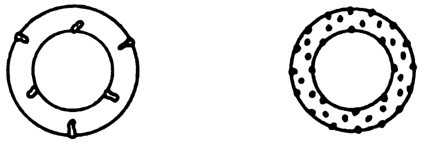
METHODS OF PROSPECTING AND EXPLORING

Recent practice in surface prospecting starts with geological mapping followed by geophysical surveying and diamond-drilling when the latter methods are justified by the preliminary examination.

Underground exploration is carried out in several ways. In the narrow veins of the Victoria and Empress sections the orebodies are opened by drifts in the ore which are designed to provide for chutes when the stopes are started. In the wide Bluff orebody where all ore from stopes is handled through bulldoze chambers to transfer levels the exploratory drift generally follows the foot wall, and from this drift diamond-drill holes are put out at right angles to the strike of the orebody to map the limit of commercial ore that forms the hanging wall.

From the results of this exploratory work and the information obtained by mining on the levels above later development can be planned readily to suit mining requirements.

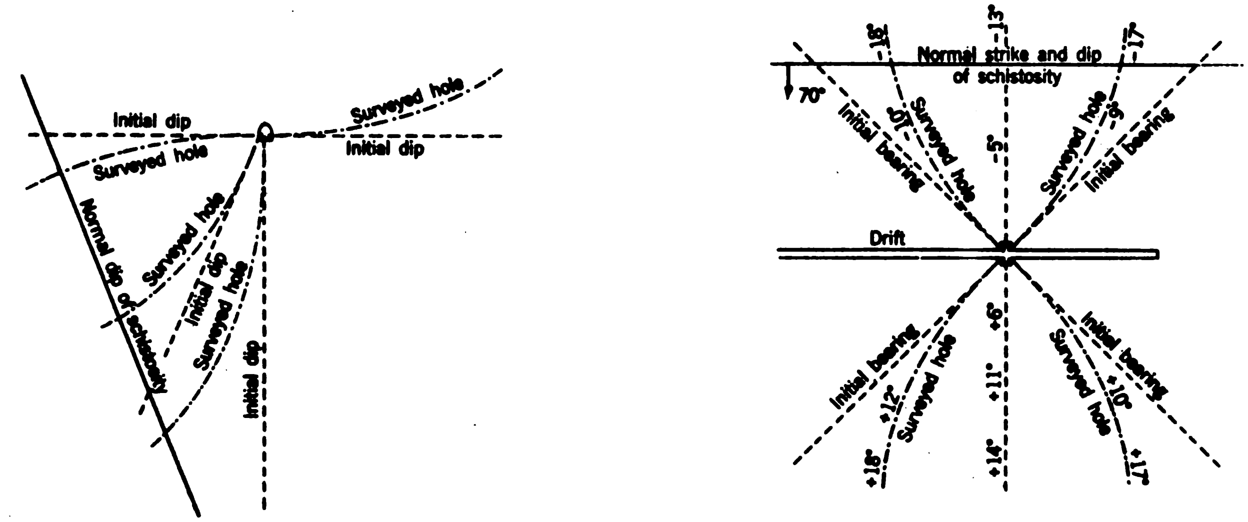
Throughout the development work and during the stoping constant geological observations are made and posted on "stope control maps." The mine surveyor is responsible for posting all new work on these maps, and the geological department is charged with the duty of plotting any geological information that may be important to the operating staff.



BLACK CARBON CROWN
(As previously used)
Carats - 22
at, say, $135 = $2,970
Average carbon loss per foot drilled, $1.15

BORTZ CROWN
(As set and used at present)
Carats - 6
at, say, $6 = $36
Average carbon loss per foot drilled, $.30

Figure 3.—Diamond-drill bits.



IDEAL SECTION AT RIGHT ANGLE TO STRIKE SHOWING DEFLECTION OF DIAMOND-DRILL HOLES IN SHEAR ZONE

IDEAL PLAN SHOWING DEFLECTION OF HORIZONTAL DIAMOND-DRILL HOLES IN SHEAR ZONE

Figure 4.—Deflection of diamond-drill holes by structure.

These maps show commercial limits of the ore, grouped assays of various sections of the block, tonnage and grade of the block as a whole, and character of ground, slips, folds or rolls in the footwall, slaty bands, etc. White prints of these maps are supplied mine foremen periodically, enabling them to visualize conditions more clearly. The geological department makes isometric projections and various mine models of critical areas, thus assisting the underground department in obtaining cheap and good extraction of ore.

DIAMOND-DRILLING

Diamond-drilling has been employed continuously for a long time. Approximately 110,000 feet have been drilled since 1918. Before 1925 all drilling was done on contract but since then, by regular company men under a diamond-drill foreman-setter supervised by the geological department. During this latter period no bits have been lost. The company owns 4 machines; 1 gas-driven, for outside work; 1 air-driven type C Sullivan of 1,500 feet capacity, and 1 3/16-inch core; 1 Longyear U. G. type air-driven machine of 750 feet capacity and 15/16-inch core; and 1 small Mitchell air-driven machine of 200 feet capacity and 13/16-inch core. Most of the holes are drilled flat and, whenever at all feasible, at right angles to the strike. Before 1930 black carbon was used almost exclusively; since then it has been used only in the reamers, and bortz has been used in the bits. Formerly the practice was to set 6 or 8 black carbons in the crown of the bit, but now 40 or more bortz are used so that each stone relieves the pressure on its neighbors and prevents shattering. (See fig. 3.) With this type of bit the diamond loss is low even in the most difficult ground. Another advantage of the new bit is the higher core recovery in soft schist, very fissile slates, and even gypsum, none of which core up well with the carbon bits. The small Mitchell machine has proved very useful, as with 5-foot rods no extra ground need be cut out for set-ups. One man operates this machine alone; he can pack it into stopes, raises, etc., and set it up with a minimum loss of time.

All long holes are surveyed, usually by the gelatin method. Experience has shown that all holes drilled toward the foot wall and horizontal turn down and that those drilled toward the hanging wall turn up. (See fig. 4.) All core is filed in specially constructed trays, each of which holds 8 rows of core 5 feet long; these trays are filed lengthwise like drawers in racks. Each tray bears on the exposed end the number of the hole and the footage contained. A card index showing the location of each is kept up to date. A member of the geological department examines all core and writes up the log for each hole. Mineralized sections are split by hand; one half is assayed, and the other half is kept in its proper tray.

SURVEYING

The several adit tunnels which afford entry to the workings greatly facilitate the connection of the surface triangulation with the underground traverse, and the transfer of an azimuth through a shaft becomes important only in the Victoria mine and in the work done below the 2,700-foot level of the Bluff mine. In all shaft connections two plumb-wires are hung, and the alinement method is used.

The 2,700-, 2,200-, 1,600-, 1,200-foot, and all levels above are or were at some time accessible by adits, and frequent connections between levels by raises help further to tie in the underground stations.

Owing to the nonmagnetic nature of the ore the compass can be used freely for stope and raise surveys. Compass surveys are started from transit points, and if the usual corrections for local attraction are applied they are sufficiently accurate.

Working maps of stopes and development, which are used as a base for control maps and assay maps, are made on tracing paper on a scale of 40 feet to the inch. White prints from these are issued to the underground department to facilitate mining operations. The same scale is used for most geological plans and sections. Main-level plans and sections are made on linen-backed, eggshell-surface drawing paper on a scale of 40 or 80 feet to the inch, depending upon the size of the orebodies involved; these constitute the permanent record. Two sizes of sheets are used, double-elephant and 40- by 60-inch. Larger scales than the 40-foot are not used for standard maps but are occasionally used for composite maps of areas of complicated geology.

DEVELOPMENT

The topography of the Britannia district permits preliminary development of each orebody through adits. As the ore reserves increased, the numerous smaller adits were superseded by a few main tunnels in which ore haulage and supply service are efficiently concentrated. These headings are driven mainly for development, as opposed to the earlier adits, which were primarily for exploratory purposes.

Jane Mine

The Jane mine was opened by adits on the 1,050-foot and 1,200-foot levels. Some stoping was done on the original ore occurrence, but the chief interest of this section now lies in a body of low-grade zinc ore, which is indicated in the old workings and will be developed further.

Bluff Mine

The Bluff orebody, originally developed by adits on the 1,000-foot and 850-foot levels, has proved to be extensive, as illustrated in figure 5. It ranges from about 50 to 200 feet in width and has been developed in depth as far as the 3,100-foot level. For convenience it is considered in three sections:

1. The old Bluff, very hard and highly silicified, was the original discovery and is mined by a combination of shrinkage stopes and gloryholes.
2. The East Bluff, a very low-grade eastward extension, is mined by the Britannia method.
3. The West Bluff, softer and less silicified, has been mined successively by shrinkage stopes, Latouche stopes, and the Britannia method.

The first transportation of ore was from the 1,000-foot level by aerial tram. Development of large bodies of ore below this level led to the driving of a main-haulage tunnel on the 2,200-foot level and the raising of No. 1 shaft from the 2,200-foot level to the 1,000-foot level. The extension of the No. 68 rock raise from the 2,200-foot level to the 700-foot level provided for the handling of muck from both Bluff and Fairview mines direct to the haulage level.

The downward extension of the West Bluff deposit was developed through No. 3 shaft, which connects the 2,200-foot to the 2,700-foot level, and the main-haulage tunnel driven on the 2,700-foot level. Further downward exploratory work has been done from the No. 4 shaft, which extends below the 2,700-foot level to the 3,500-foot level, and by the extension of the 4,100-foot haulage tunnel. The latter tunnel is driven from the head of the mill 240 feet above sea level.

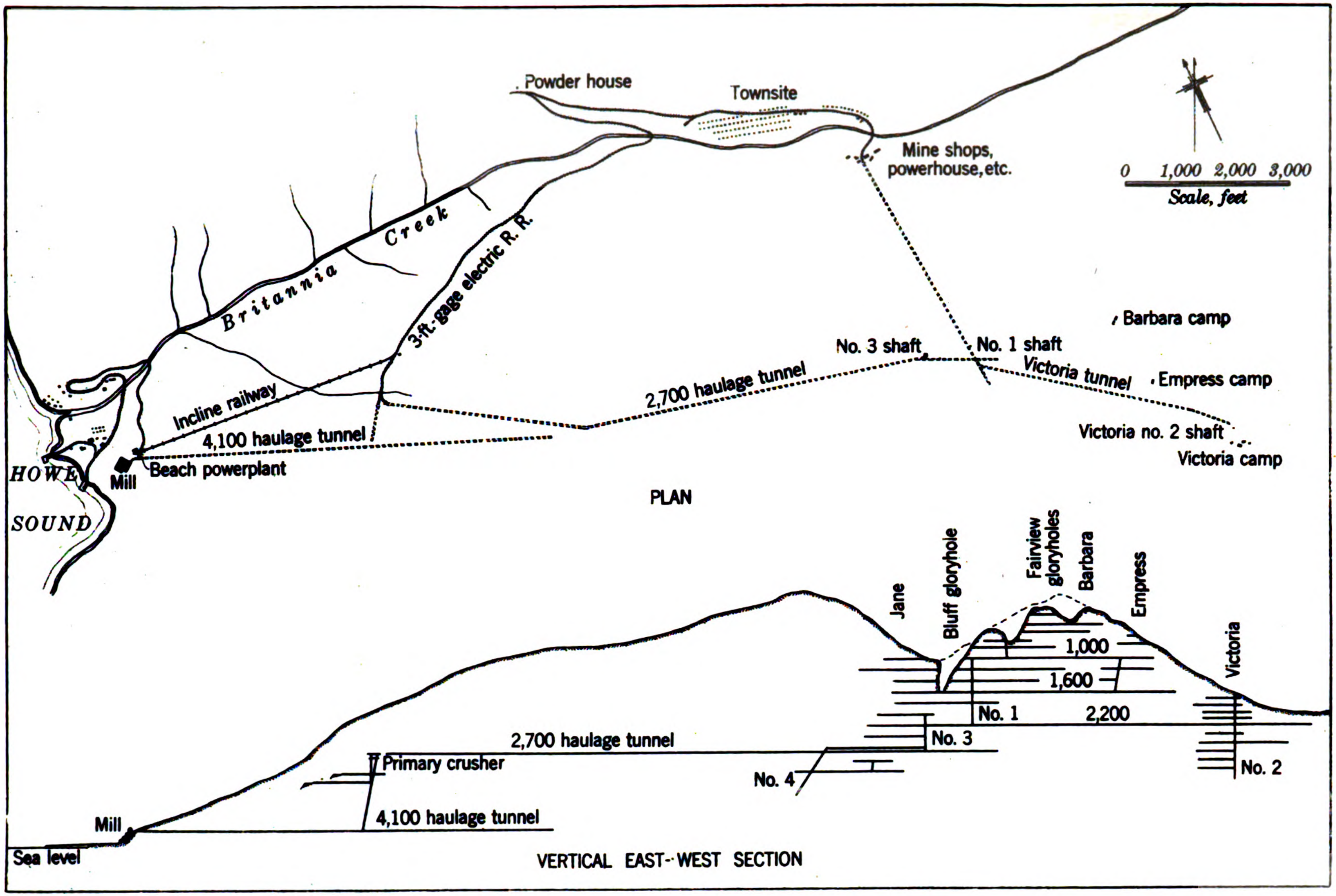


Figure 5.—General relation of mine levels, adit tunnels, and surface plant.

Fairview Mine

The Fairview ore deposit consists of a series of 12 parallel veins. To develop the upper section of this mine above the 1,000-foot level, No. 2 shaft was raised from the 1,000-foot to the 500-foot level. The veins were opened in the ordinary way by crosscuts and drifts and the earlier mining was by shrinkage stopes, some of which were as long as 1,300 feet. The ore was handled through the No. 68 rock-raise system, as described above. Development of the Fairview veins below the 1,000-foot level was from No. 1 shaft.

Empress Mines

This mine was first developed by adits on the 700-, 850-, 1,000-, and 1,600-foot levels, which were later connected to the workings off No. 1 shaft; the 700-foot level is the highest. One rock-raise system handles the ore above the 1,000-foot level, and another carries the ore from the 1,200- and 1,400-foot levels to the 1,600-foot level, where it is trammed to the main No. 68 rock raise. The deposit consists of two parallel veins, and development is simple.

Victoria Mine

The Victoria mine consists of seven parallel veins containing relatively high-grade ore compared to that now mined in other sections of the property. The mine was first opened by adits from the Furry Creek Valley on the south side of Britannia Mountain, and connection was made later on the 2,200-foot level. The major portion of the Victoria tonnage, however, has been developed by the sinking of No. 2 shaft. Originally sunk from the 1,900-foot level, this shaft was extended to the surface to allow for installation of the larger hoist necessary for increased depth.

The development of the mine includes a system of waste-filling raises which draw from surface gloryholes in the glacial overburden and necessitate special precautions against surface water. These are described under Mining.

Shafts

At Britannia there are 2 shafts in the Bluff mine, 2 in the Fairview mine, and 1 at the Victoria mine. The No. 1 shaft is a three-compartment shaft, 18 feet 8 inches by 9 feet 6 inches, over-all dimensions; the 2 hoisting compartments are 7 feet 6 inches by 6 feet in the clear. It is the main service shaft on the property. All supplies for the Empress and Barbara camps, many of the supplies for the Victoria camp, and all timber from the Victoria sawmill are handled through it. Double-deck cages are operated in counterbalance, the cables for which are 1 1/4 inches in diameter. An Allis-Chalmers hoist with 6 1/2-inch drums is direct-connected to a 350-hp. motor, giving a rope speed of 800 feet per minute. The hoist is equipped with a Lilly overwind control, and the brakes are air-operated. The other three shafts in the Fairview Bluff mines are smaller. Their place in the general scheme of development has been described.

The Victoria No. 2 shaft is a vertical three-compartment shaft; the hoisting compartments are 5 feet by 4 feet 6 inches in the clear and the manway 4 by 5 feet. The shaft extends from the surface at 1,750 to a sump 93 feet below the 3,150-foot level. The 2,200-foot adit tunnel passes just behind the shaft, extending 150 feet for car room.

The Canadian Ingersoll-Rand hoist is a double-drum, single-reduction, geared type driven by a 250-hp. a-c. 440-volt motor. The hoist is equipped with Lilly safety devices which control the cages at the surface, bottom loading pocket, and, when hoisting, at the midshaft dump.

Shaft-Sinking

Figure 6 shows the method used in sinking the Victoria shaft and in drilling the standard shaft round. The blasting set is similar to an ordinary shaft set but is covered with 1/2-inch plate and held together with 1-inch rods. The shaft crew comprises 4 men, 1 of whom is a jigger boss, and during mucking the skip tender, who is required to cage cars and operate the safety doors. For safety the doors have electrical contacts; when they are fully open a green light shows in the hoist room.

Although the shaft is wet, the quantity of water to be removed is not large. A No. 5 Cameron sinking pump is required at the end of the mucking cycle and during drilling; 2 3/4-inch wet pluggers are used, with 7/8-inch hexagonal steel. The 4 men set up, drill, and blast their round in 8 hours. Mucking requires 1 1/2 shifts for a 4 1/2-foot break. Muck is shoveled or scraped into a 22-cubic foot pan, which is lifted by a tugger hoist and dumped into a standard mine car resting on the special sinking cage shown in figure 7. The skip tender replaces the loaded car with an empty while the pan is being filled. Waste trammers take the loaded car from the station to a stope being filled.

The tugger and main hoist are used both to lower and raise the blasting set. Sets are spaced on 5-foot centers. The wall and end plates are 10 by 10 feet and the dividers 8 by 10 feet with 4- by 8-foot scabs above for extra support against squeezing. At and above stations and loading pockets 12- by 12-foot sets are used.

No. 4 Shaft.- The No. 4 shaft is sunk on a 58° incline to prospect the ground below the 2,700-foot level. It is 13 feet 6 inches, outside dimensions, and has 1 hoisting and 1 manway compartment. Muck is dumped into an 80-ton pocket, which discharges through a standard air-operated finger gate chute on the 2,700-foot level.

The ground in this shaft is a hard, siliceous ore, which stands well. The shaft crew comprises 4 miners, 1 of whom is a jigger boss, and the hoistman. Shaft timbers consist of 10- by 10-foot sets on 6- by 8-foot centers and 6- by 10-foot rail stringers covering 2 sets. Thirty-pound rails are used for the skip.

The 58° slope, coupled with the hard ground, makes the use of the standard 4-foot drifter advisable. Two crossbars with two machines on each bar are used; the round drilled is similar to that in the Victoria shaft. Muck is shoveled into a 40-cubic foot standard inclined shaft skip with 48-inch wheel gage. A 4-inch air line, 2 water lines, and a 16-inch ventilation line are carried forward with the timbering. Two lengths of 20-foot extension rails, beveled on the upper end to allow the skip to run on them, are used. Generally, 3 sets are timbered at a time, and the face is kept about 10 feet below the blasting sets. Costs of this work are shown under Summary of Costs.

Drilling and Blasting

The ground ranges from the very hard cherty rock of the East Bluff to the soft "silver schist" of the Fairview mine. In general, the Victoria, Fairview, and Empress mines are medium; the West Bluff, medium to hard; and the East Bluff, very hard.

At Victoria 70 feet of drilling per miner shift compares with 60 feet in the much harder East Bluff ore.

The length and spacing of the holes depend upon the class of work and the kind of ground. In general, 10-foot 6-inch steel is used in the West Bluff and East Bluff. Holes up to 20 feet deep are drilled in Latouche stoping, requiring a very large starter bit with consequent loss of drilling speed. Special sets are maintained for Latouche work and for small drifts. The standard set for other work finishes with a 10-foot 6-inch steel.

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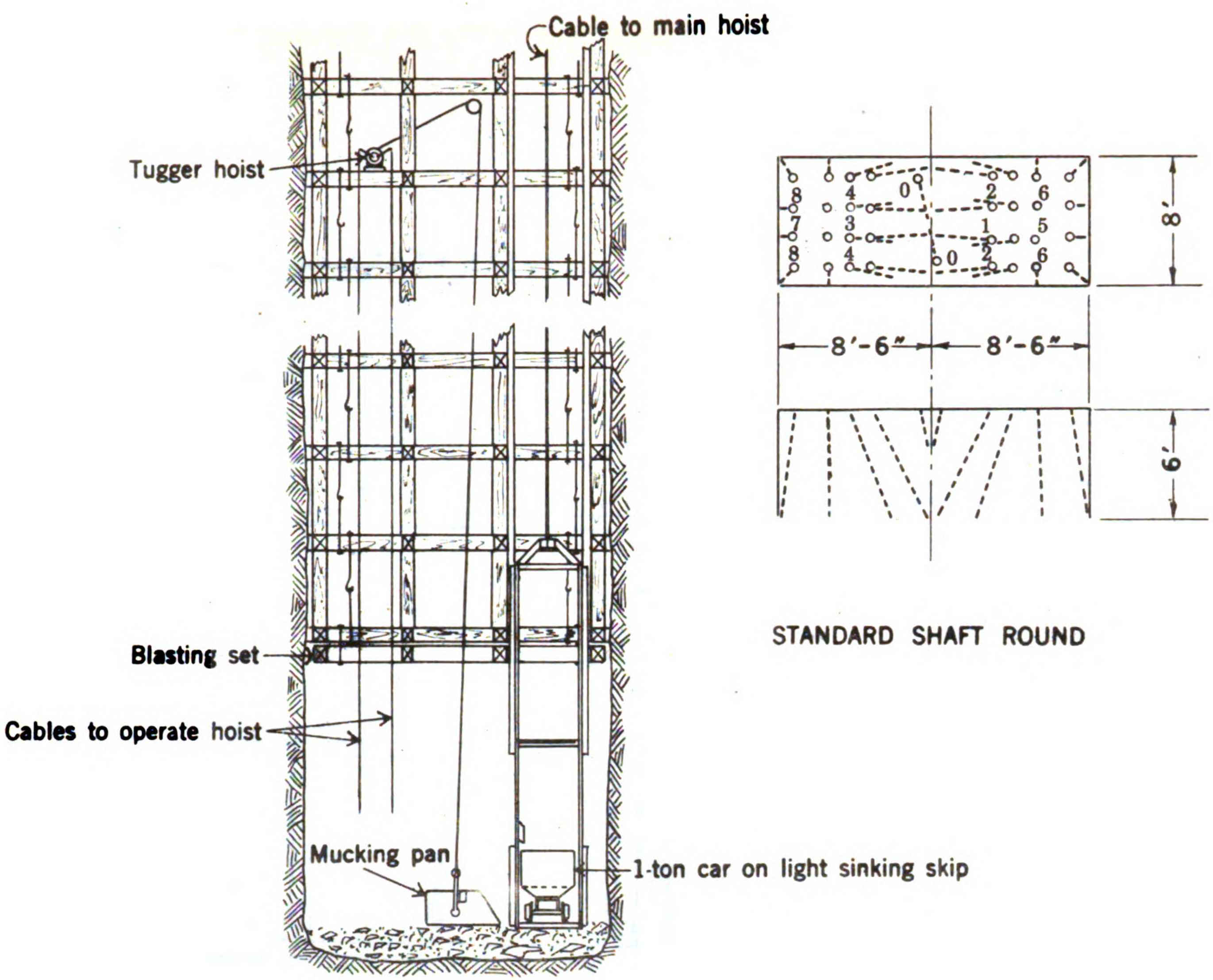

Figure 6.— Detail of sinking operation, Victoria mine.

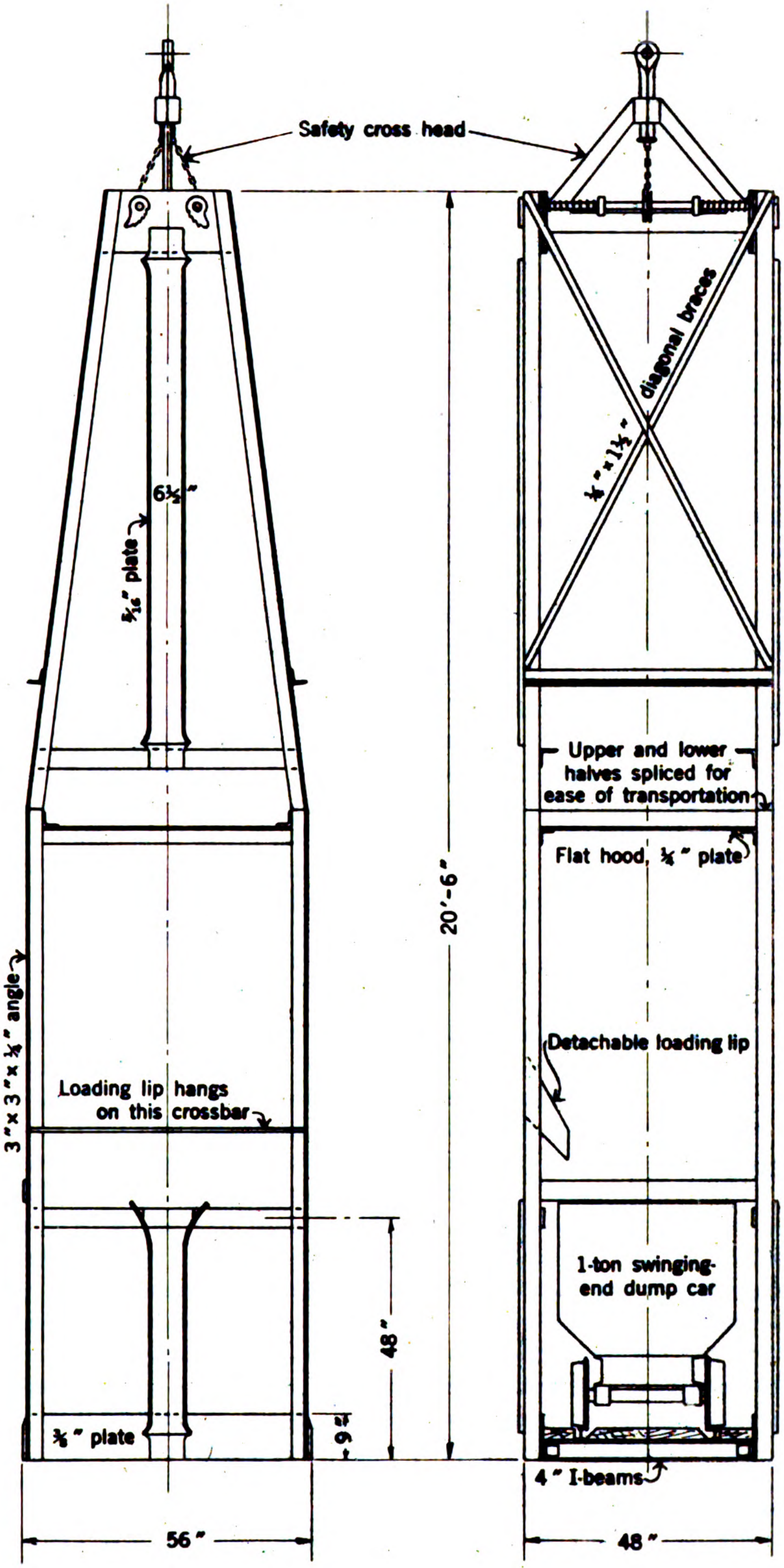

Figure 7.—Shaft-sinking cage.

All machines use 1-inch hexagonal steel. The present practice is to use a double-taper crossbit with 7 1/2° and 15° taper. Leyner starters for general work are 30 inches, over all, and carry a 2 1/2-inch gage; 1-foot changes with 1/8-inch gage change up to 10 feet are used.

The special sets for small drifts have a 1 7/8-inch starter gage, with a change of 1/8-inch per foot run up to a 6-foot 6-inch steel with 1 3/8-inch gage. This increases drilling speed and reduces breakage of steel and wear and tear on machines.

Thirty-inch starters with a 2-inch gage are used in stoping. Changes are in 1-foot lengths with gage change of 1/8 inch. Stoper steel is not cut longer than 8 feet. All plugger steel has 1 5/8-inch gage and is cut in lengths up to 6 feet. For shaft work at Victoria the starters were 2 feet with 1 3/4-inch gage; 1-foot changes with 1/16-inch gage up to 8 feet are used.

At present all Leyner steel has lug shanks. Drill tests are made with anvil block steel; more time is lost in down holes, especially in certain ground, with anvil block steel. Shanking expense, however, is reduced, and a considerable decrease in shank breakage may be anticipated.

All drills are of the wet type. At present a 4-inch drifter is used in the hard Bluff ground. A 3 1/2-inch drifter has proved very satisfactory in the less siliceous ore at Victoria; all are one-man set-ups. Here too, a hand-rotated stoper has given excellent results in raising. In other parts of the mines self-rotating stopers are used.

On bulldoze chambers 2 3/4-inch wet pluggers are used with collared steel. A few heavy pluggers equipped for 1-inch lug steel are employed where the ore is very hard. Broken lengths of Leyner steel that otherwise would have little value can thus be utilized.

Machine bars are made of 3-inch extra-heavy pipe, ranging from 30 inches for powder drifts to 11 feet for high stopes. Machine arms are 18 and 30 inches in length, longer arms being more general in the Victoria cut-and-fill rill stopes.

Powder

Various types and grades of powder are used at Britannia to suit the numerous uses and varying hardness of the ore.

Stumping powder of 20 percent strength is used in logging operations. In the Victoria and Empress square-sets 30-percent ammonia forcite powder is used; on Fairview and West Bluff bulldoze chambers, 30 percent gelatin, and in the Victoria cut-and-fill rill stopes and all East Bluff and West Bluff stoping, 40 percent gelatin.

For powder blasts 60-percent dynamite and 60- and 40-percent ammonia powder are employed; 100-percent nitroglycerin has also been tried. The nitroglycerin comes in 12 1/2-pound bags and is easily and quickly loaded. This method of packing powder was developed especially for the work at Britannia. The low-percent powder gives a heaving effect, whereas in hard and more fractured ground the faster powder is thought to give better fragmentation. One restriction on the choice of the most efficient explosive for this mine work is imposed by Government regulations forbidding the use of straight dynamite in underground operations.

For development work 40-percent gelatin is employed and in difficult ground 60-percent gelatin for the cuts.

Fuse

The fuse used is a smooth, black-finish, cotton-countered safety fuse, burning at the rate of 1 foot in 40 seconds. For wet holes the fuse and caps are dipped in "fuse waterproofing compound." All fuse is prepared and capped by the fuseman and tied in bundles of 25. Generally it is cut in 2-, 3-, and 5-foot lengths for the bulldoze chambers and for stoping and development work, in 7-, 8-, and 10-foot lengths. Near bulldoze chambers or other convenient places boxes are erected and wired for electric lights; a light placed in the bottom of the fuse box assures the fuse being kept dry.

All fuse are fired by no. 6 detonators. In shaft and powder-blast work electric detonators are used. When powder drifts are blasted cordeau fuse is worked through all powder to increase the velocity of detonation of the charge. Powder drifts and winzes are stemmed with broken muck from the last few rounds; this is piled in the drift and thrown back over the charge after loading is complete.

All rounds are blasted by at least two men, who see that all entrances are guarded.

Ventilation is generally good, allowing blasting at all hours, if the drilling is ready. However, as far as possible rounds are blasted either at lunch time or at the close of the shift.

Air Pressure

Air pressure ranges from 80 to 90 pounds at the drill, dropping from the initial powerhouse pressure of 100 pounds. From the powerhouse the air passes through a 12-inch pipe for 3,900 feet and then into several receivers at the No. 1 Fairview shaft. From the receiver an 8-inch line leads to No. 1 shaft and branches off on each level to smaller pipe. A 6-inch line leads from the receiver to Victoria and an 8-inch line to No. 3 shaft and the West Bluff.

RAISING

Timbered Raises

Two types of raise are used on the property. In the narrow veins such as those at Victoria and Empress raises are timbered. The slope is 70° or steeper, in general following the pitch of the vein. The raises usually are started over the sill timbers, one set having a chute and the other a manway. The chute and manway are separated by a row of stulls on 5- to 7-foot centers; the chute is lined with 4-inch planks. A strong bulkhead is placed over the manway, and entrance to the face is through a small door in the chute just below the bulkhead. Muck is kept in the chute to this level. Several rounds are taken out above the bulkhead, and the stulls and chute are again raised and the bulkhead moved up. Staging rests on 4- to 6-inch round sprags or on 10- by 10-foot timbers, depending upon the type of ground being drilled. It generally is found most efficient to raise the chute when the back reaches a point about 20 feet above the bulkhead. The cuts are then blasted, and the benches are blasted on completion of the timbering. The muck from bench holes covers the bulkhead, and there is less concussion and less chance of breaking timbers than when the whole round is blasted in one operation.

Cribbed Manway Raises

Cribbed manways in timbered raises have replaced the stulled and lagged type just described in parts of the mine. This practice has given excellent results and by speeding up the advance has lowered the cost of raising. Whereas the former method necessitated cutting hitches, measuring, cutting, and placing heavy stulls, and spiking on lagging, the present construction is of framed timber which need only be placed and spiked. An added advantage is that the cribbing can be reclaimed and used again.

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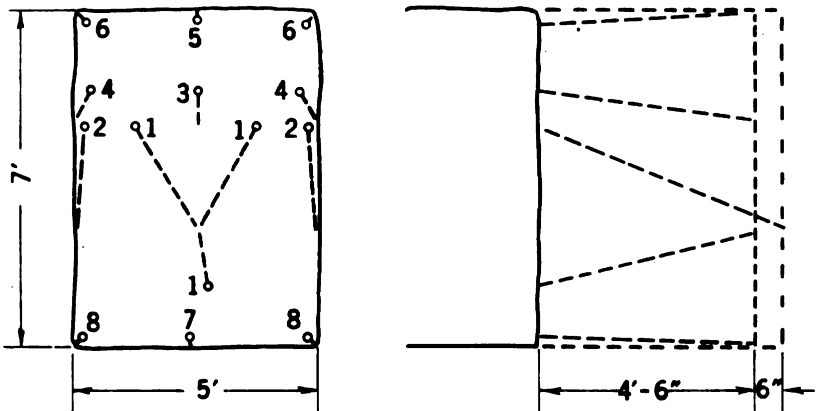
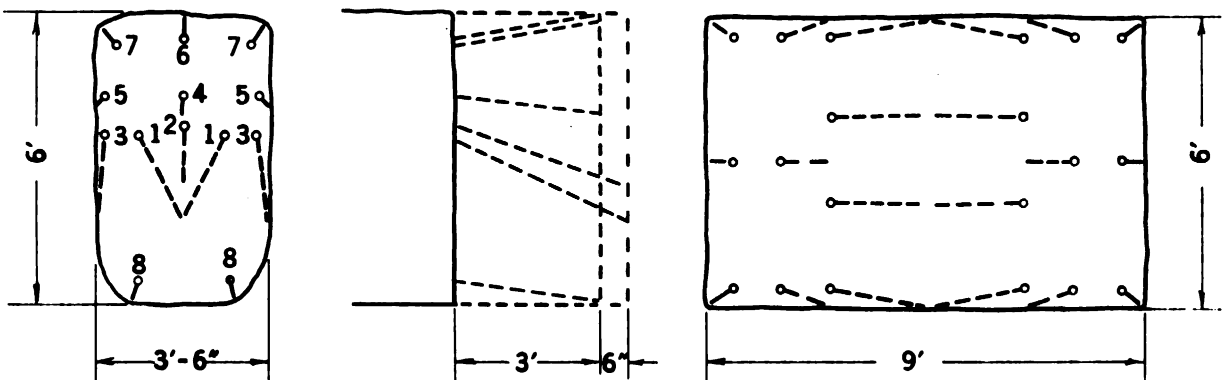
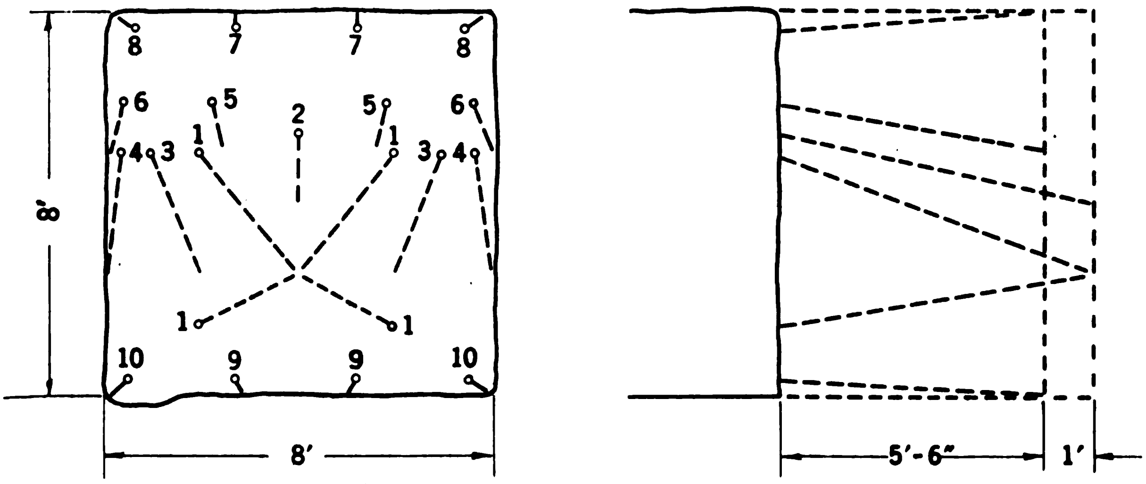


14-HOLE CROSSCUT ROUND, SOFT GROUND; DRILLED FROM VERTICAL BAR SET IN CLEAR FACE, VICTORIA MINE



13-HOLE ROUND IN "COYOTE HOLE" DRIFT, DRILLED FROM CROSSBAR OVER MUCKPILE, HARD GROUND; DRIFT SECTION DESIGNED FOR WHEELBARROW MUCKING

20-HOLE ROUND IN 6'×9' RAISE, MEDIUM TO HARD GROUND



21-HOLE ROUND IN 8'×8' HAULAGE DRIFT, HARD GROUND; DRILLED FROM TWO VERTICAL BARS SET IN CLEAR FACE

Figure 8.—Standard rounds (numbers refer to firing order).

The cribbing used is a standard size, 6 by 10 feet on edge and 3 feet 6 inches in the clear; this size is used also for the cribbed manways in the filled rill stopes.

This method, of course, is unsuitable for service raises, which require retimbering after completion, but it is well-suited for waste or rock raises, which must be stripped of all timber after completion.

Untimbered Raises

In harder ground raises are generally untimbered. They are usually started from a bulldoze chamber so that no timbering is required, and the muck flows as broken to the chamber. These raises are driven on a slope of 50° to 57°. Machine and steel are carried to the face after each blast until the raise has advanced 50 feet. A bulkhead covering half the raise is then put in. Machines, hose, etc., are placed behind it until the raise has been advanced another 50 feet, when another bulkhead is placed. A tugger hoist is set up at the bottom, and the skip is dragged over the rough bottom to the bulkhead, above which the steel, etc., must be nipped by hand.

Ladders are made of 3- by 4-inch fir with 1-inch pipe rungs over 3/4-inch round rods. The rods go through the sidepieces and are bolted. These ladders are held in place by old drill steel bent in a U to pass over the side of the ladder into a hole drilled in the bottom. They stand the blasting well and are generally taken out at the completion of the raise and used elsewhere.

Drifting and Crosscutting

On account of the wide variations in the drilling and breaking qualities of the ground, size of drift, and speed requirements, drifting practice varies considerably in different sections of the mine.

In the Victoria, Fairview, and Empress mines 5- by 7-foot drifts are driven, being designed for hand-tramming from small chutes. One miner sets up, drills, and blasts a round every shift, the advance ranging from 4 to 4 1/2 feet in drifts and 4 1/2 to 5 feet in crosscuts. The typical round drilled is shown in figure 8. Mucking is done on a separate shift, two men being allowed to the round.

In the Bluff it is seldom possible for one miner to drill the round in a shift except in small drifts, such as the powder drifts used in the Britannia method, where a 3-foot round is broken with 13 or 14 holes in a 6- by 3 1/2-foot excavation. Owing to the speed requirement and the short round to which breaking is limited by the small size of the heading, work in these drifts proceeds in three shifts, and drilling is done over the muck pile from a crossbar. Mucking from these drifts is by wheelbarrow for distances up to about 75 feet; in longer drifts track is laid for a half-ton car. In larger drifts such as main haulages (8- by 8-feet) two machines are employed. Unless extra speed is required, two vertical bars are set in a clear face, and mucking is done on a separate shift.

In ground difficult to break cuts are blasted and reblasted if necessary when the square-up is shot. In easier ground the whole round is blasted together. In working places where it is undesirable to blast in two operations on account of smoky conditions, if the ground is difficult to break it is common practice to use 60-percent gelatin in the cuts and 40-percent in the square-up.

4,100-Foot Level Haulage Extension

The 4,100-level haulage tunnel is the main haulageway at the mill level, handling all mine production from one main rock raise. This is now being extended for a new rock raise approximately 14,000 feet from the portal.

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The next important level above this point is the 2,700-foot level, the main haulage level handling ore from the mine rock raises to the crushers and thence to the 4,100-level rock raise.

Before 1929 there were no workings between these levels other than crusher stations and control chutes on the rock-raise system, but about the beginning of that year a development campaign was begun which included the sinking of the No. 4 shaft below the 2,700-foot level and the opening of levels at 2,900, 3,100, 3,300, and 3,500 feet.

By the end of 1930 enough ore had been blocked out below the 2,700-foot level in this area to justify extension of the 4,100-level haulage some 10,000 feet to tap this new block of ground, thereby eliminating the necessity for hoisting this ore and opening up a great deal of virgin country for exploration.

Equipment

The drilling equipment is standard, a four-drill carriage of conventional design. The heading is being driven 10 by 12 feet, making the drill carriage larger than usual. Short air and water hose are 1 1/4 and 3/4 inch in diameter, respectively, and the main air and water hoses are 3 and 1 inch. Line oilers are mounted on the manifold. Heavy 4-inch machines are used.

The main air line is 6 inches for 4,000 feet and is then reduced to 5 inches. The face extension is 3-inch pipe. This is carried not more than 300 feet ahead of the permanent line. The water line is 2-inch with a 1-inch extension. Air is supplied by a 1,250-c.f.m. compressor delivering air at 100 pounds pressure per square inch.

One-inch hexagonal steel with 1 1/8-inch round lug shanks is used according to standard Britannia practice. Bits are reduced to the minimum possible size to give maximum drilling speed. Sets are 3 to 11 feet with a gage change of 3/32 inch per foot run, starting at 2 1/4 inches and finishing at 1 1/2 inches.

The machines were equipped with a special shell 4 inches longer than the standard to facilitate making a 2-foot change in softer ground.

Behind the drill carriage is a steel car on which, in addition to steel, are carried spare machines, short hose, and such quickly replaceable parts as side rods and crank handles.

The standard round of holes is shown in figure 9; four extra holes are used in ground difficult to break.

Rounds are fired electrically from a special firing circuit, which has a Square-D switch not less than 300 feet from the face and a firing switch not less than 1,000 feet back; the latter is of the spring type, which normally remains closed and in this position short-circuits the line as a safeguard against stray currents. Both are padlocked; the keys are carried by the shift boss. The powder used is 40 percent forcite gelatin is 1 1/8- by 8-inch cartridges. Electric caps used are no. 6 size, delays no. 1 to no. 5.

The mines are ventilated by suction through a 22-inch fan pipe, using a 42-inch Western blower. Auxiliary ventilation in the face is obtained by blowing the compressed-air line wide open after blasting.

Mucking is done with an Osano-type scraper slide, as described under Mechanical Loading. (See figs. 10 and 11.) Rolling stock includes ten 120-cubic foot side-dump cars built in the Britannia shops, one 8-ton Westinghouse locomotive for switching, and one 15-ton General Electric locomotive for main haulage.

Crews

Under conditions prevailing at this time low cost is a more important consideration than speed, so that the aim is to attain maximum efficiency with small crews. The heading crew

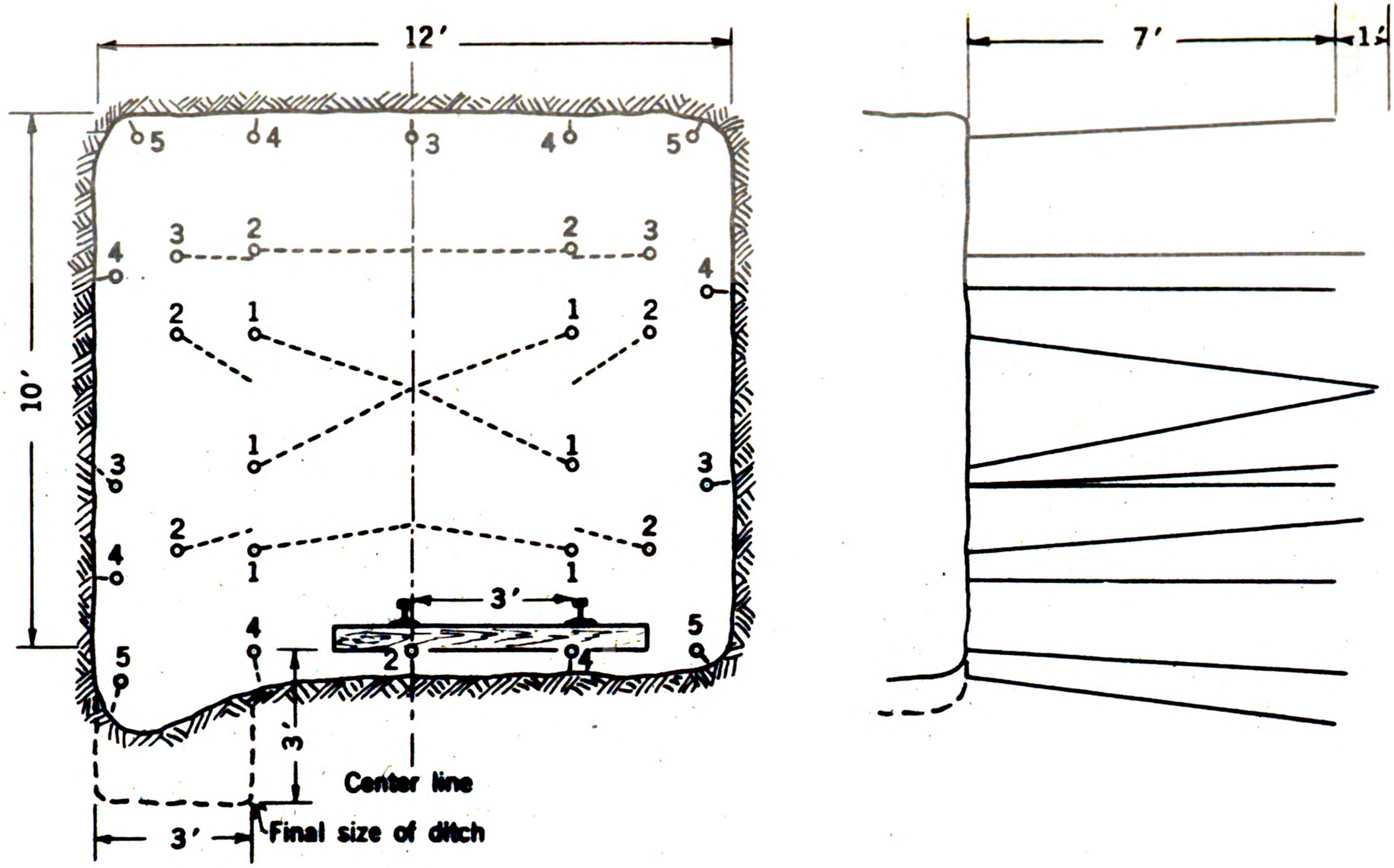


Figure 9.—Standard round, 4,100-level tunnel; figures opposite holes denote delay used.

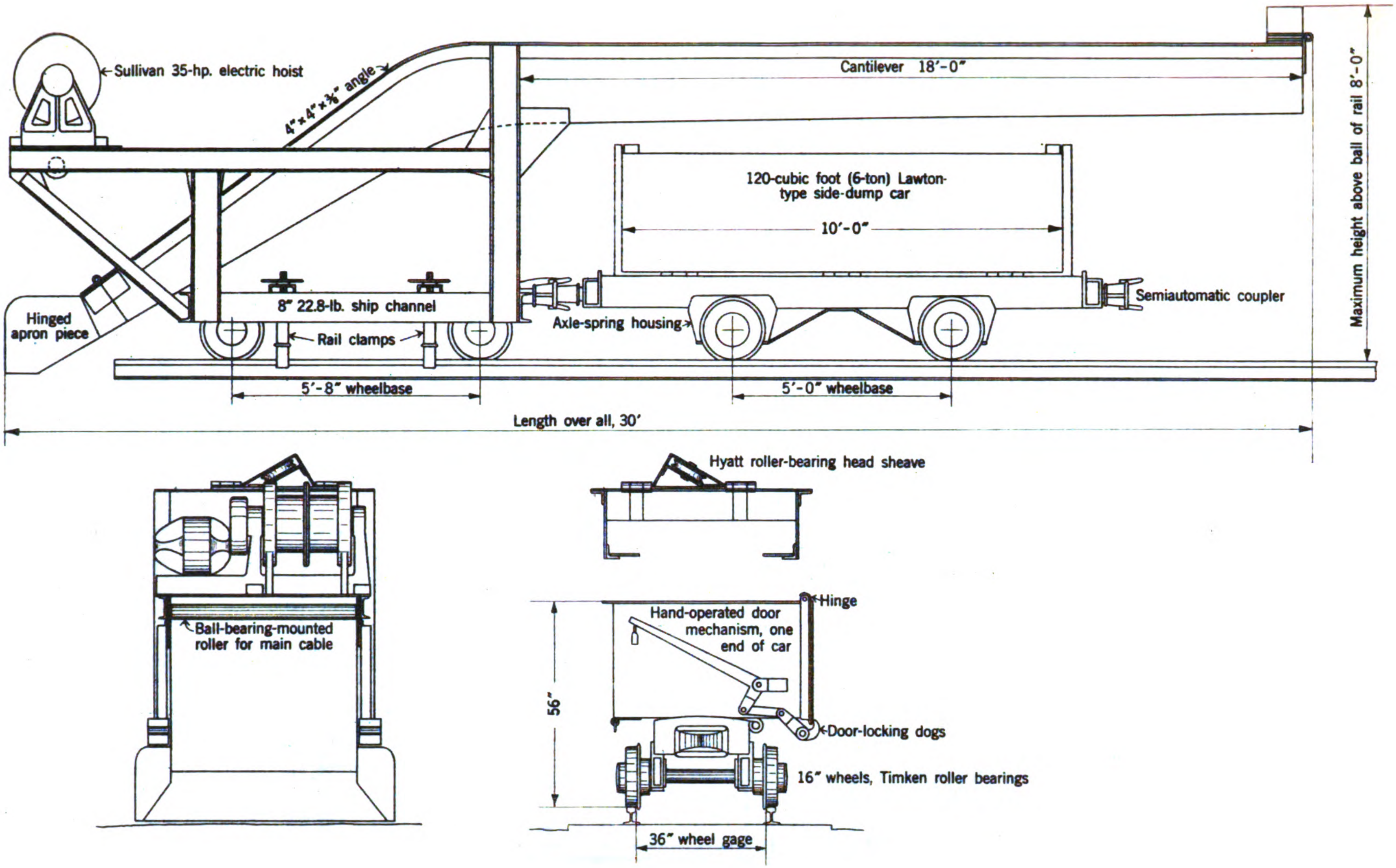

Sullivan 35-hp. electric hoist
4"×4"×⅜" angle
Cantilever 18′-0″
Maximum height above ball of rail 8′-0″
120-cubic foot (6-ton) Lawton-type side-dump car
10′-0″
Semiautomatic coupler
Hinged apron piece
8" 22.8-lb. ship channel
Rail clamps
Axle-spring housing
5′-8″ wheelbase
5′-0″ wheelbase
Length over all, 30′
Hyatt roller-bearing head sheave
Ball-bearing-mounted roller for main cable
Hinge
Hand-operated door mechanism, one end of car
56″
Door-locking dogs
16″ wheels, Timken roller bearings
36″ wheel gage

Figure 10.—Scraper-slide mucking machine and 120-cubic foot (6-ton) side-dump mucking car.

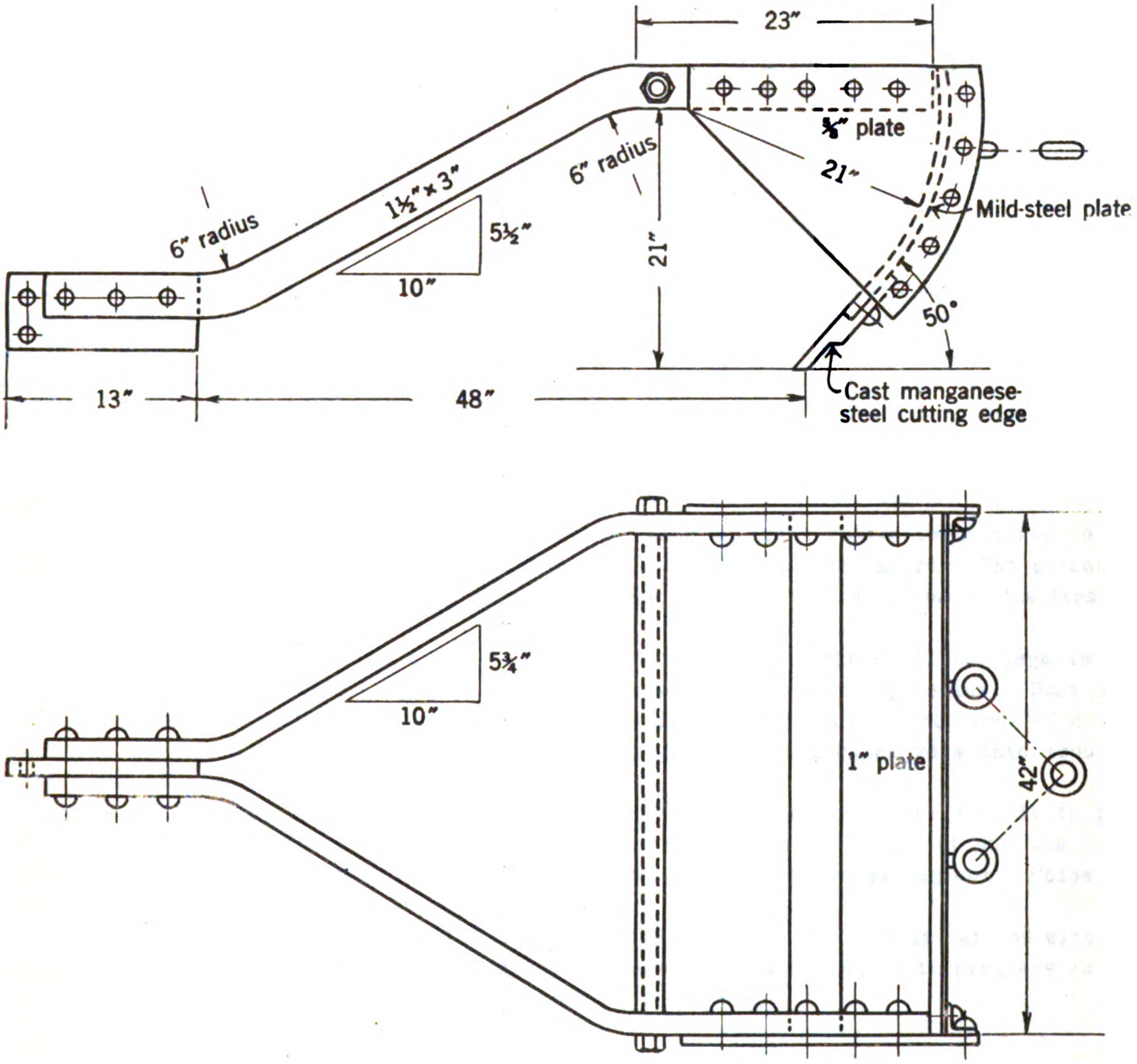


Figure 11.—Scraper for scraper slide.

on each shift comprises 1 shift boss, 4 miners, 2 muckers, 1 motorman, and 1 brakeman; 1 trackman and his helper and 1 ditchman are on steady day shift and 1 steel sharpener and his helper are at work in a special shop at the portal. One man disposes of the waste; he trams it on the 4,150 level to a surface dump from a chute drawing the pocket below 4,100 level into which waste from the heading is dumped. Mechanics and electricians are called out as required. The whole is in charge of a tunnel foreman directly responsible to the mine superintendent.

Cycle of Operations

After a blast the crew proceeds to the face, 2 miners bar down, 2 rig hose and machine for drilling holes for the Lewis wedges, 2 muckers clean out for the scraper slide, and the train crew bring in cars and slide. A hole is drilled in each wall at the face, wedges are driven in, a chain is stretched across, and the tail sheave is hung on this; the mucker is meanwhile clamped to the rails and connected to the 440-volt, 3-phase, a.-c. power line, and mucking begins.

While a car is being filled the train crew hang an empty on the car switcher, the full car is pulled back, and the empty is dropped on the rails and pushed to the mucker. Filling cars averages 3 to 4 minutes and switching, 1 to 3 minutes, according to distance. The car switcher is moved up about every 500 feet.

One side of the heading is scraped out first; when the tail sheave is switched to the other side 2 or 3 men clean along the wall with shovels and hand scrapers. The permanent rail is kept 30 feet from the face so that the scraper can dig to the bottom of the ties ove the whole area.

After mucking is completed a light rail extension is laid, the drill carriage is run over this to the face and set up, the staging is erected, and drilling begins. Some side holes and relievers can be drilled as well from one machine as another. The order of drilling is so arranged that these holes are drilled last. If one machine gets into trouble, another can take an extra hole and save delay.

While drilling is in progress 1 man cuts powder and prepared primers; when it is finished 2 men blow out the holes while the drill carriage is being taken out and the round loaded, the blasting circuit is tested, and the connecting wires are strung out. Holes are connected in series.

A drainage ditch 3 feet wide and 3 feet below the bottom of the ties is carried with the heading. The necessary plugging and blasting are done while drilling is in progress in the face, and mucking is done by hand at all points of the cycle.

Ground Conditions

The ground ranges from very hard and blocky to very soft and highly schistose. The hard ground is often wet, and at times water pressure is so great that wedges must be driven into the holes to keep the powder from being forced out. Drilling time ranges from 1 1/4 to 5 1/2 hours, but 2 to 2 1/2 hours is usually sufficient.

Timbering was necessary in one place only for about 40 feet.

Performance

The average advance is one 6-foot round per shift, which can be maintained in any but the hardest ground.

The total cost of this work up to the present time has been $25.83 per foot, including a proper proportion of all constructional and equipment expenses, such as purchase and installation of compressor, erection of steel shop, etc., and of capital charges necessary to equip the completed tunnel with 100-pound track and trolley wire for haulage of ore.

SQUARE-SET MINING

Square-set mining is used chiefly at the Empress and Victoria mines. The walls in general are weak and the ore itself often blocky. The veins are much narrower than the orebodies in the Fairview and Bluff sections.

At Victoria this method has been found almost as cheap as the cut-and-fill rills. Floors are on 7-foot 6-inch centers and posts, on 6-foot centers both ways; 10 by 10 posts and caps and 6 by 10 girts are employed. Chutes are generally placed on 36-foot centers longitudinally with the manway in the next set. Muck slides are run to the chutes to reduce shoveling.

The veins range from 1 to 5 or occasionally 6 sets in width. The mining section includes the entire length of the ore between 2 chutes or 36 feet of stope. Four sets high are mined, and then the mining crew is moved to another stope and the four floors are filled. A section is worked from sill to sill in this manner. Muck slides are also placed for filling so that virtually no shoveling of fill is required. The extreme corners from waste chutes are not filled, as this would require shoveling. The details of a square-set stope are shown in figure 12. Typical sill timbering is shown in figure 13.

Machines are generally set up ahead of timbers; flat holes are drilled, breaking to the mucking floor below. Timbermen line the chute, slab the gob for filling, prepare the manway at the front end of the section for the timber slide, and place square-sets behind the miners. In the large stopes the crew consists of 1 miner, 1 timberman and helper, and 2 muckers. Steel is nipped to and from the stope by the general level nipper. Twenty-two-cubic foot cars running on Timken roller bearings are used for tramming. One trammer handles 30 to 60 cars a shift, depending on conditions at the chute and distance from the shaft pocket.

Cut-and-fill Rill Stopes

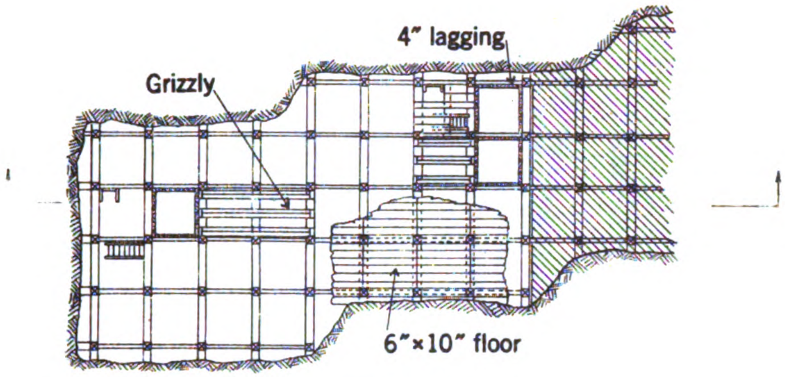
Many of the narrow veins at the Empress and Victoria mines are very adaptable to cut-and-fill rilling. In these stopes the holes are drilled from the rill toward the chute. Service is from the top, and drill steel is taken out at the bottom. Holes are drilled at 20°, as shown in figure 14; 15 to 20 feet of ground at a time are removed above the filling The last face in each bench is drilled and left; this practice has the advantage of giving a good start to a rill stope and saves much time and trouble in starting a bench, as at times the filling comes so close to the face that the initial set-up is difficult.

Crib chutes, 4 feet 6 inches in the clear, of 10- by 10-inch timber are carried up as mining advances. Next to the chute crib manways 6 feet 10 inches on edge and 3 feet 6 inches in the clear are used. Originally chutes were stulled and lined with 3-inch planks, but as the depth increased and with it the need for ventilation crib chutes were adopted. The heavier timbers and crib construction makes them easier to maintain; some of them will be kept open for the life of the mine.

Filling

Filling at the Victoria and Empress mines is of major importance.

It has been found that the best results are obtained by not opening up too much ground at one time. When large volumes are mined the time for filling is excessive and the walls



PLAN ON MUCKING FLOOR

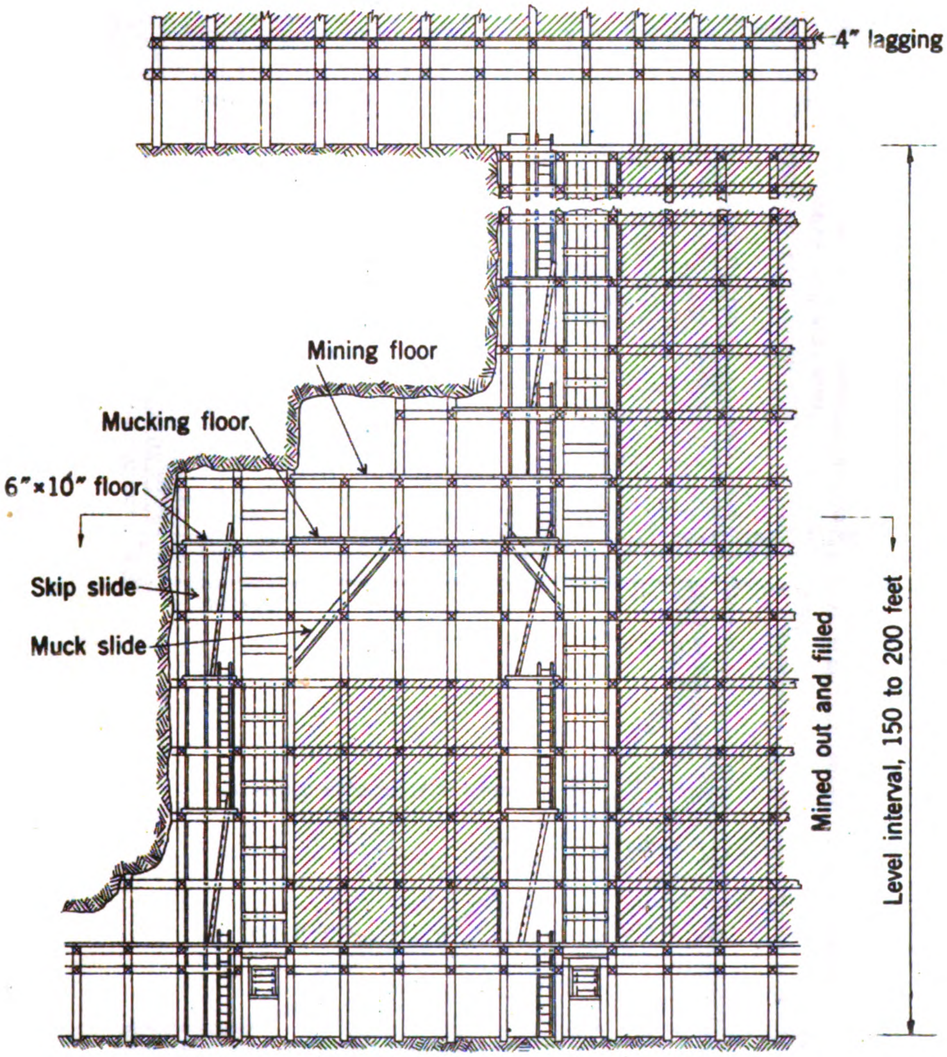


Figure 12.–Square-set mining, Victoria mine.

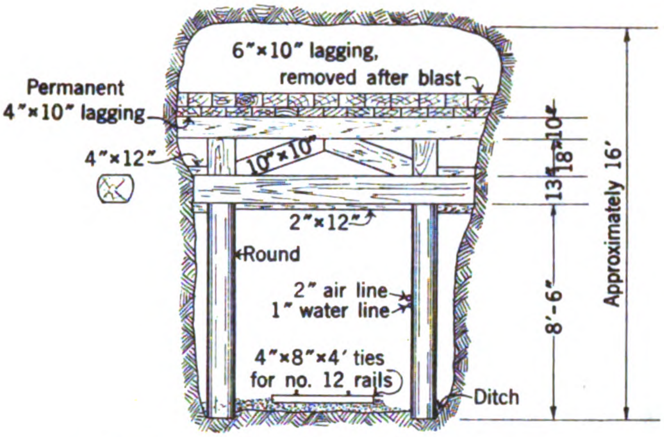


Figure 13.—Typical sill timbering, Victoria mine.

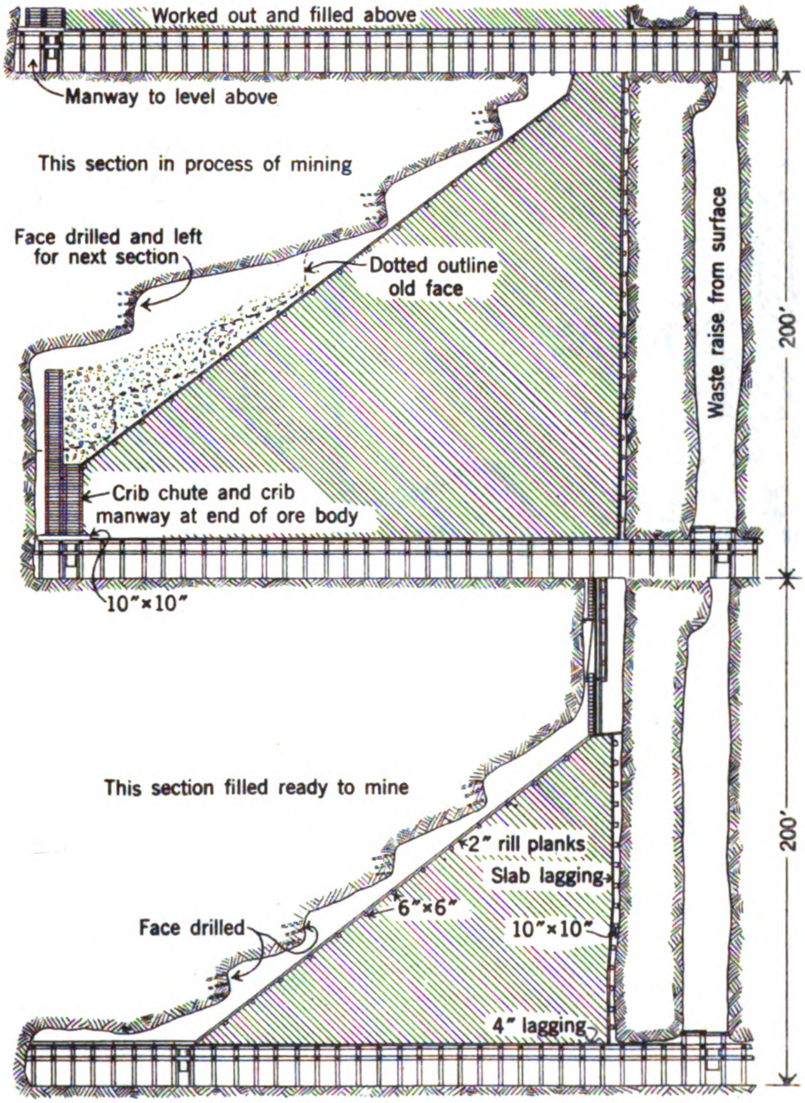


Figure 14.—Ideal section of rill stopes, Victoria mine.

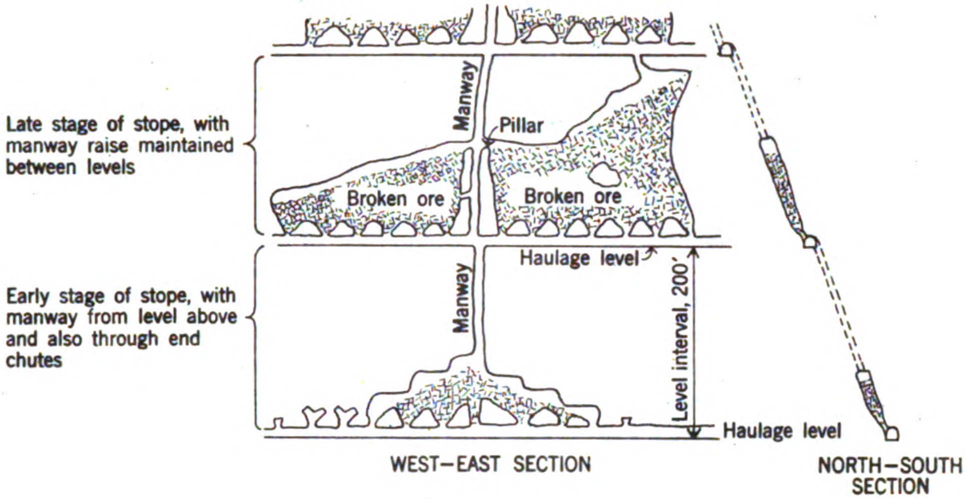
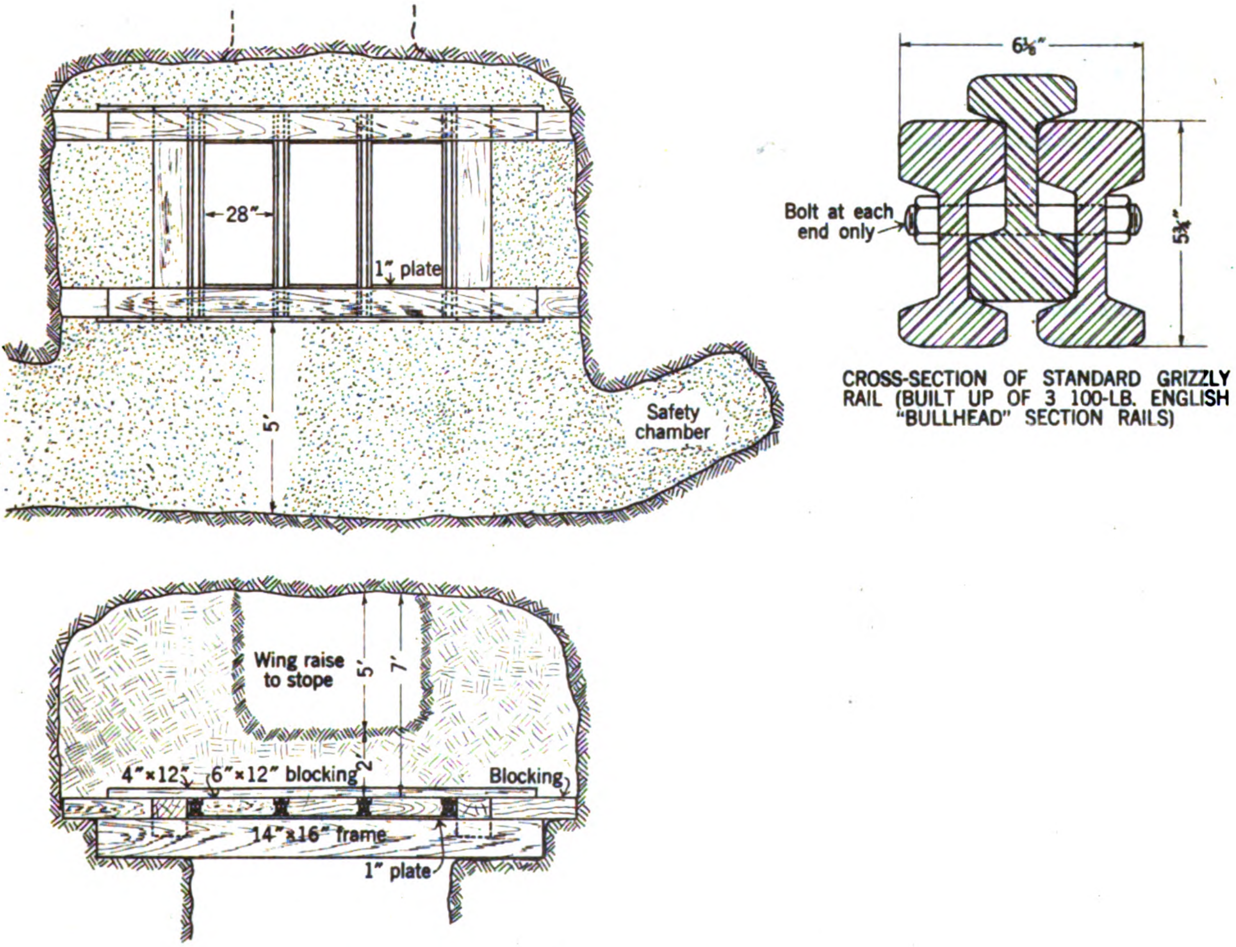

Late stage of stope, with manway raise maintained between levels
Early stage of stope, with manway from level above and also through end chutes
Manway
Pillar
Broken ore
Broken ore
Haulage level
Manway
Level interval, 200'
Haulage level
WEST–EAST SECTION
NORTH–SOUTH SECTION

Figure 15.–Section of Fairview shrinkage stope.



CROSS-SECTION OF STANDARD GRIZZLY RAIL (BUILT UP OF 3 100-LB. ENGLISH "BULLHEAD" SECTION RAILS)

Figure 16.–Plan and section of standard bulldoze chamber.

open up badly, so that tight filling is impossible. Loosely filled stopes settle continually and greatly increase maintenance costs for sill timber and track on levels above.

In general, glacial material is used for filling; at Victoria it covers the bed rock to an average depth of 100 feet. All development waste is also used, but this is negligible except during shaft-sinking. The glacial material, containing considerable clay with the sand and boulders, makes an excellent fill. It sets, especially when wet, very tightly, with virtually no shrinkage.

At the Victoria mine 2 waste gloryholes feed 2 waste raises on the east and west ends of the orebody, which extend to the lowest levels. On the top level is a bulldoze chamber. One miner breaks boulders and passes the material through 100-pound grizzly rails spaced on 10-inch centers. On the various levels are arc gate-control chutes through which waste may be drawn into cars or bypassed to the level below. One miner is employed steadily between the two gloryholes. He plugs or bulldozes the larger boulders and by means of coyote holes keeps the gloryholes well filled. Two shifts or more are required on each waste grizzly. The small grizzly openings require considerable plugging but assure excellent drawing and tramming conditions below. With the depth now reached at Victoria storage space is ample, and waste is always abundant. Stopes are thus quickly filled.

As tramming is often against the grade and the fine silt leaking from the car keeps the track dirty, 2 trammers are required on each car; they tram 20 to 80 cars a shift, depending upon the distance trammed and wetness of the waste. In wet seasons particularly cars often contain considerable water.

Settling tanks near the waste chutes help to localize the cleaning of ditches. These are made with several partitions and are not over 2 feet deep.

Small Shrinkage Stopes

The upper levels of the Fairview mine were first mined by square-setting and later by shrinkage stopes; chutes are placed on 33-foot centers. Before stoping is started a raise is driven to the level above, and a pillar is left to support this raise so that a manway between levels is maintained throughout the life of the stope. The remaining ore in the upper levels of the Fairview mine is being extracted by large-scale methods, but shrinkage stopes are still used in moderate-size orebodies on the lower levels.

Chute raises are driven east and west from each chute and connected. Service usually is through a chute at one or both ends until the center of the stope is too high to continue entry from the bottom; service is then transferred to the raise.

The stope thus begins as a shrinkage rill, but later when service is entirely from the top the flat-back form is followed. The ground stands well over the widths of 12 or 15 feet usually mined, and no particular mining difficulties are encountered.

A section of a typical Fairview shrinkage stope is shown in figure 15.

Large Shrinkage Stopes

The Bluff orebody, which is 50 to 200 feet wide, was also first mined by shrinkage stopes. In the old Bluff the ground is exceptionally strong, and tremendous excavations will stand well without other support than the broken muck. The practice in this section was to take a cut along the foot wall, leaving a belly to the hanging wall which could be brought down with a relatively small number of long holes. Plugger men were employed constantly in drilling the large boulders so brought down, as these stopes were all drawn by means of chutes.

At greater depths the stoping values are found mainly in the West Bluff, a western extension of the Bluff orebody in which the ground is much more treacherous. It became dangerous to work far from the footwall, and as this prevented the plugging of the large boulders chutes were replaced by bulldoze chambers, so that secondary breaking was done on the drawing level.

These conditions led to the use of a modification of the Latouche mining method. By this method the ground after being undercut is broken by drilling long holes from chambers cut from stope raises. A large tonnage of ore was mined by this method, but the method has been superceded by the Britannia.

Bulldoze Chambers

In handling the large shrinkage stopes and in carrying out the large-scale stoping operations under the Britannia method bulldoze chambers have been indispensable. Here most of the secondary breaking is done. A typical bulldoze chamber is illustrated in figure 16.

Grizzly rail construction caused much trouble in the early stages of mining; the present method is the outcome of many experiments and has been found very satisfactory. The grizzly consists of 3 or 4 bars spaced to give clear openings of 24 to 36 inches.

Each bar is built up of three sections of 100 pounds to the yard bullhead rail, as shown in figure 16. The bars lie on cap plates of 1-inch steel plate, which protect two sides of the 14- by 16-inch fir grizzly timbers.

The bullhead rail is standard on the British railroads and is imported especially for this work. The short span is important, as the bending moment about the center of the composite bar is thereby kept at a minimum.

The spacing of rails depends on the nature of the rock and on the drop between the grizzly and the transfer chute. The tough East Bluff rock, which shows little tendency to shatter in its fall down the raise, is passed through a 26-inch grizzly, whereas the more highly sheared and softer rock in the Fairview section, most of which travels 500 feet through the transfer raises, is passed through openings as large as 36 inches.

A bulldoze-chamber crew comprises 1 miner and 1 mucker. The floor plan is averaged to give plenty of working room without unduly increasing the floor space, which must be shoveled clear of muck after plugging boulders.

These men are compelled to wear a safety belt, in the back of which a D ring is firmly secured. When the grizzly is open they must attach to this ring a length of 1/2-inch rope, the other end of which is attached to an eye-bolt in the back of the chamber. The attachment is quickly made at either end by means of a safety snap hook. This hook is specially designed to carry a heavy load.

The safety chamber (fig. 16) is cut so that the inside man may retreat to safety from a rush of muck without stopping to unfasten his rope. His partner retreats through the exit on the other side.

Bulldoze chambers are laid out to take the best advantage of the ground to be stoped and in older sections of the mine to take advantage of narrow work already completed. Usually they are placed 70 feet center to center, and the footwall row is placed as near as ground conditions will permit to the footwall itself. (See fig. 17.) The raise representing the throat of the chamber then points up the footwall and permits drawing in that direction to the best advantage.

Wet machines are used exclusively in blockholing. Two types of pluggers are used, depending upon the rock to be broken; one weighs 46 pounds and the other 65 pounds. One-inch hollow, hexagonal steel is used, largely the many shorter lengths resulting from the breakage of longer steel in drifts and stopes.

A self-rotating stoper is available for all bulldoze chambers; these are particularly valuable in this work, as the drill can be used to put in a hole in a dangerous corner with

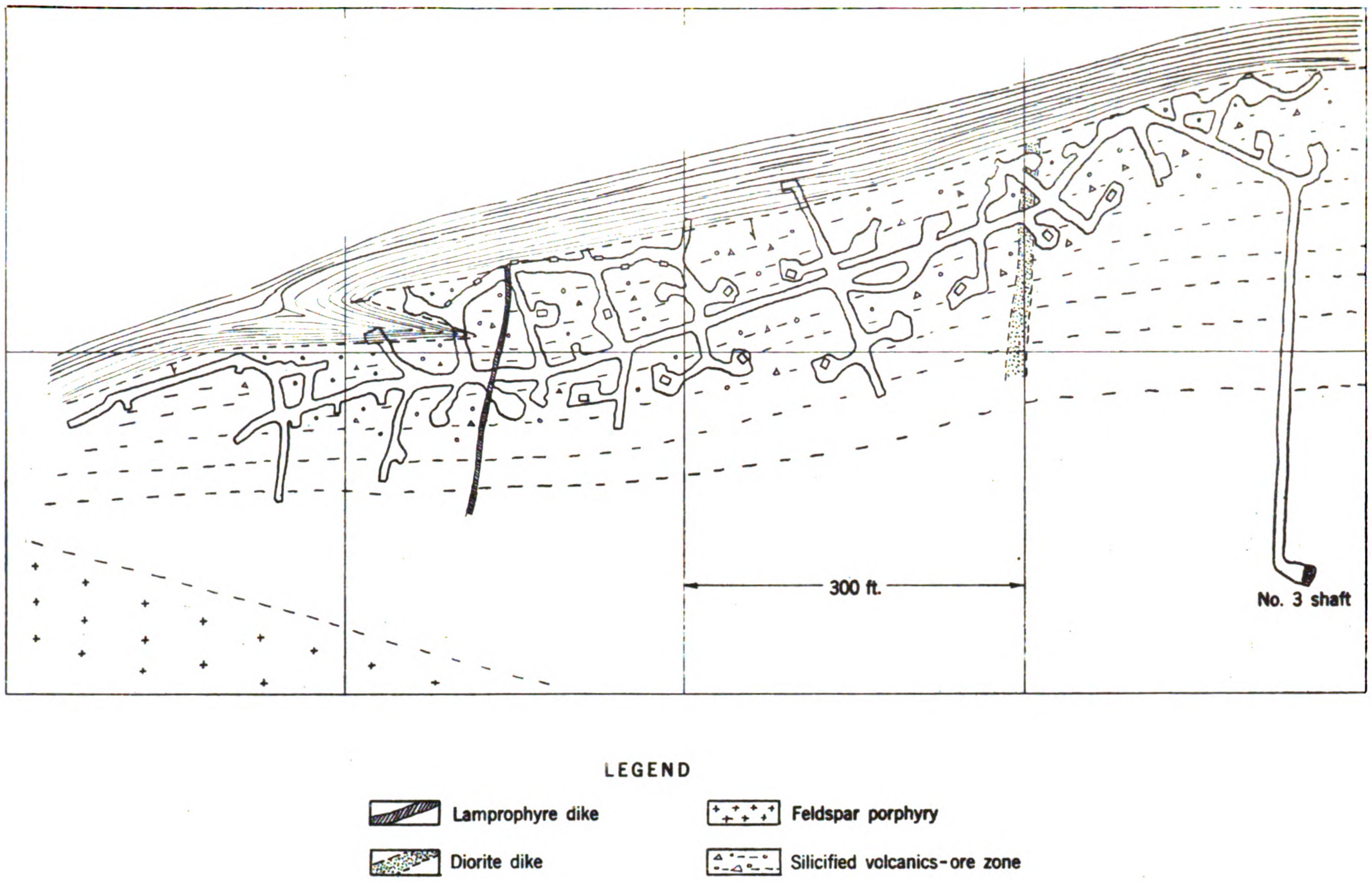


Figure 17.—2,000 level, Bluff mine; geology and development.

the operator at a safe distance.

Occasionally, when large pieces of rock drops over the chambers, it is possible to set up a bar and drill 10- to 15-foot holes with the regular 4-inch drifting machines. Forty percent gelatin powder in 1 1/8- by 8-inch sticks is used exclusively in the bulldoze chambers. It is not ideal for blasting hang-ups because of its lower velocity but has been found to be the best all-round powder for use in work involving blasting hang-ups, drill holes, and an occasional mud cap.

All rock possible is broken by plugger holes, but most of the powder is used in getting the big rocks into position where they can be drilled.

Each bulldoze chamber is provided with an air whistle to give warning before and during all blasting operations.

The following figures give an approximation of the labor, explosives, and power used in putting the very hard East Bluff ore through the bulldoze chambers.

It should be remembered that similar work can be done in the Fairview schists for much less.

Explosives consumption	pound per ton	0.5
Labor:		
In bulldozing	man-hour per ton	.16
In stoping	do.	.11
Power (including air used in blowing smoke)	kw.-hr. per ton	.40

Britannia Mining Method

The Britannia mining method was developed by the author to meet the necessity for low costs and increased safety. After some experimental work a section of the West Bluff mine was laid out for stoping by this method, and in the early part of 1931 when it was decided to mine the very hard East Bluff orebody the method was modified to fit this work. The general scheme of operation is:

1. Establishment and development of a bulldoze-chamber level or an alternative level for chute drawing.
2. Complete undercutting of a section of the orebody. The orebody is usually cut from foot to hanging wall but may be laid out in various ways, depending upon its size and shape.
3. Development of block for use of powder blasts.
4. Control of ore drawing. Details of this operation depend upon the size and height of the orebody being mined and the hardness and friability of the ore.

The bulldoze chambers are uniform in design and are constructed as described.

In undercutting the practice is similar to that employed in the big shrinkage stopes. In the East Bluff large areas can be excavated safely with but few pillars; in the West Bluff more frequent support is necessary. However, unless the ground is very soft there is no practical limit to the size of the block that may be undercut if adequate pillar support is provided. The only limitation is that individual pillars must not be so large that they cannot be conveniently drilled off and blasted out in one operation. The method is thus adapted to a wide range of ground conditions. Undercuts have been made up to 200 feet in width.

For the development of the block one or more service raises are necessary, according to the size of the block to be mined, but within fairly wide limits the positions of these raises do not affect subsequent mining and may be selected more by convenience of service.

The number and location of such raises are governed by the sublevel development that follows and are considered an individual problem for each stope.

Sublevel Development

From these raises small drifts are driven to locate powder pockets; the first lift is usually 25 to 30 feet. This sublevel work also explores the ore at that particular horizon. Methods vary, but the usual practice is to open the sublevel by a drift on the foot wall and clearly define the foot and hanging walls by diamond-drilling short holes therefrom.

When enough information has thus been gathered powder pockets are located and the points so fixed are reached by crosscuts from the footwall drift. The pocket itself is formed by sinking a few feet below the drift level, either vertically or at a flatter angle, so that the broken muck from the last 2 or 3 rounds can be saved and thrown over the powder as tamping. The explosive is confined more effectively in this way than is possible in a flat drift. Powder for loading these pockets is not packed in cartridges but in heavy paper bags, each containing 12 1/2 pounds.

Drifting follows the practice described under Drifting and Crosscutting.

Breaking

The method of mining is to blast down each lift by stages, retreating lengthwise of the stope, usually toward the service raise.

Under ideal conditions the preparation for and even the breaking itself can proceed simultaneously on several lifts in the same block.

The lower lifts must be advanced so that the work on the upper lifts will not be blocked. This arrangement gives the whole stope the appearance of a rill in which the broken ore or waste follows the mining operation. Calculation of the quantity of explosive to be used is a matter of judgment based on experience and is very important. When such powder pockets are blasted into a gloryhole, it is usually wise to load the pockets generously rather than risk a poor break. In underground stoping, however, the effect of too heavy blasting may break the hanging wall and increase caving. On the other hand, the effect of underloading is equally bad; the block of ground is not broken down but is left in place as a shattered mass, which is both difficult and dangerous to enter with subsequent drifts, and the old powder-pocket location may be completely lost.

Drawing

The ore is drawn off through bulldoze chambers in the usual way. In East Bluff ground the walls of the stope stand so well that control of drawing is unnecessary. In softer ground, however, as much ore as possible must be left in the stope to support the hanging wall, and the program is therefore so arranged that just enough muck is withdrawn to make room for the next blast about the time this blast is ready to be fired.

Supervision

The method demands close and careful supervision, as perfect timing and coordination between various operations are essential. This work must therefore be planned comprehensively and the salient features plotted on stope-control maps so that routine surveying will quickly disclose any departures from plan. The way in which this method is modified to suit conditions and the necessity for coordination are best illustrated by a description of its application to the East Bluff orebody.

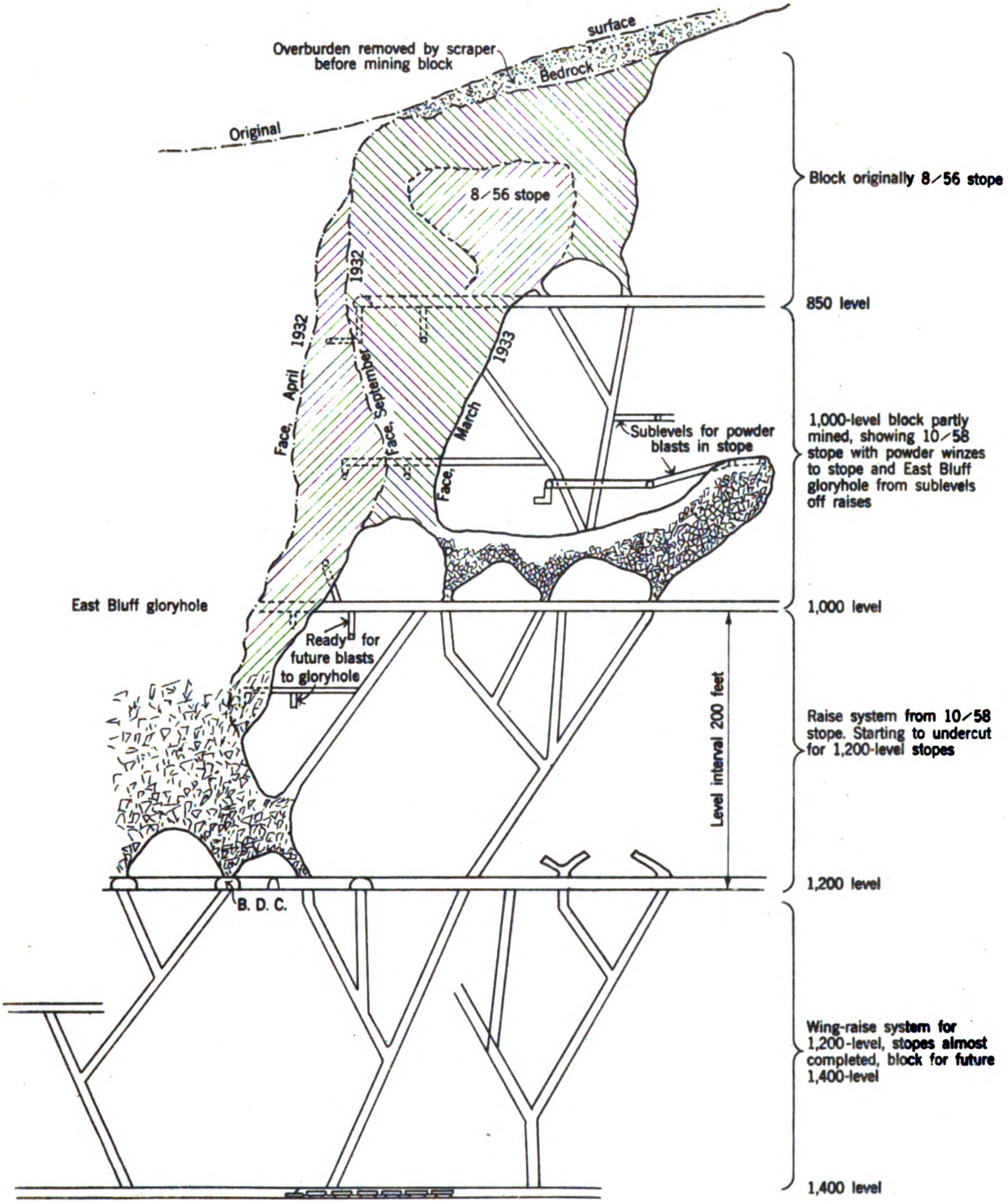

surface
Overburden removed by scraper before mining block
Bedrock
Original
8/56 stope
Block originally 8/56 stope
850 level
1932
Face, April 1932
Face, September 1932
Face, March 1933
Sublevels for powder blasts in stope
1,000-level block partly mined, showing 10/58 stope with powder winzes to stope and East Bluff gloryhole from sublevels off raises
East Bluff gloryhole
1,000 level
Ready for future blasts to gloryhole
Level interval 200 feet
Raise system from 10/58 stope. Starting to undercut for 1,200-level stopes
1,200 level
B. D. C.
Wing-raise system for 1,200-level, stopes almost completed, block for future 1,400-level
1,400 level

Figure 18.—Ideal section showing application of Britannia method to East Bluff ore body.

Britannia Method in the East Bluff

The details of the Britannia method in this case are illustrated in figure 18. The block of ore mentioned extended from below the 1,200-foot level to the surface at about the 700-foot level and lay east of the old Bluff gloryhole. Intermediate levels are the 850-foot, so-called, being actually 125 feet below the 700-foot level, and the 1,000-foot level, 200 feet below the 850-foot level.

It was important to extract all the ore above the 850-foot level before drawing points were lost by caving and before possible hanging-wall caving in the gloryhole filled the bulldoze chambers with waste and cut off the good ore above.

It was found possible to handle the ore from the west end of the orebody through the old gloryhole; this was accordingly broken by means of regular coyote-hole operation.

On the east end 9,000 cubic yards of overburden was first removed from above the mining area by a 75-hp. double-drum electric hoist operating a 5-ton crescent-type scraper. Scraping was carried to a maximum depth of 40 feet. Meanwhile, the No. 8/56 stope was undercut on the level below. As soon as the undercut was sufficiently opened powder blasting was begun, and the remaining block of ground above the 850-foot level was removed by a series of 12 blasts.

Operations were so timed that this block had been mined out, and the most westerly bulldoze chambers on the 850-foot level had just been drawn empty when the level was caved by firing a powder pocket which was one of the series used in breaking the west end of the orebody into the old Bluff gloryhole.

Similar operations are now being carried out in this orebody on the 1,000-foot and 1,200-foot levels.

The Britannia method has the following advantages:

1. Flexibility. Not only can the system be freely modified to suit conditions in the original planning of the stope, but it can also be readily adapted to meet changing conditions encountered as mining progresses.
2. Control. The method permits better control over the breaking of the ground than either straight shrinkage stoping or the Latouche method under conditions prevailing in the West Bluff mine.
3. No permanent pillars are left to be recovered by auxiliary methods.
4. In carrying on the mining work there is a constant retreat from the worked-out areas into virgin ground.
5. Safety. As all working excavations following undercutting are of minimum size, the risk of injury from falls of ground is greatly reduced.
6. Cost. This method has been found to give very low costs.

Gloryholes

Gloryhole mining was first practiced in the Bluff orebody where the deposit itself was large enough to warrant its use. Later large gloryholes were opened up in the upper Fairview section, where the closely spaced, parallel veins with some mineralization between them made cheap, large-scale breaking preferable to expensive selective mining.

In both mines gloryholing was originally carried out by a system of benches. Drilling was done by pluggers or tripod machines.

Later, however, the problem became one of handling still lower-grade blocks of virgin ground as well as that left around the walls of excavations made by previous gloryholing and by underground stoping operations which connected with the gloryholes. The solution was found in the application of "coyote-hole blasting", so that the latest gloryhole methods are virtually those of quarrying except that all rock is handled by gravity through standard bulldoze chambers to the regular rock-raise system. The extent of each blast varies with the nature of the rock. In the East Bluff not more than 25,000 to 50,000 tons of burden usually are broken by 1 shot, but in the Fairview ground as much as 150,000 tons have been broken at once.

It is sometimes necessary to break a small percentage of waste rock in order to take all the ore, but the costs of this method are so far below those of all others that the cost of handling the extra tonnage over an efficient drawing and gravity transportation system such as has been built at Britannia is easily offset by the tremendous reduction in breaking costs.

Subsidence

Shrinkage stoping, followed by gloryholing and later by powder-blasting in the upper section of the Fairview orebody, has resulted in a caving and subsiding area of approximately 15 acres. Locally, this is known as the caved zone. For several years a member of the geological department has made a careful examination of this area at least twice monthly and submitted to the superintendent notes on changes or new developments therein. A set of control maps is carried for this area; on these cracks and slips, falls, and movements are noted. It has generally been possible by this means to foresee any changing conditions and to make mining or drawing plans accordingly.

The footwall, which is usually soft and dips at 70°, and 1 or 2 post-mineral faults act as rough boundaries for the subsiding area. The schistose nature of this section of the mine greatly aggravates subsidence, as the foliations make ideal gliding planes. In one section a large feldspar porphyry dyke retarded subsidence for some time and allowed the accumulation of stresses which were ultimately relieved by heavy falls. Largely because the surface of this area is very rugged and because it was necessary at times to draw from more than one level, rotational movements were set up, as well as the more progressive drawing movements. In general, the ground has subsided in a relatively orderly fashion.

Transportation

The transportation problem at Britannia is influenced largely by the mountainous nature of the country and the large area over which the ore deposits are spread. The ore must be transported about 3 miles from the mines to the mill, which is ideally located on tidewater; the history of expanding production at Britannia is also one of improved transportation facilities.

The ore was run successively over an aerial tramway with a capacity of 700 tons per day, a double-track incline which handled 1,600 tons per day, and a 3 1/2-mile, 3-inch gage electric railroad which handled 5,000 tons per day and dumped into a main transfer raise on the 2,700-foot level.

The surface railroad has since been replaced by a 2 1/2-mile tunnel on the 2,700-foot level, drawing from a comprehensive rock-raise system to which all of the mines are tributary. This partly eliminated the handling of heavy trains over heavy grades and made the ore transportation independent of weather conditions except insofar as they affected the nature of the muck handled.

A steady output of 7,000 tons per day has been maintained, and greater tonnages could be handled if required. The present routes of main ore transportation are illustrated in figure 5.

Present plans call for the extension of the 4,100-foot-level tunnel to handle all ore mined below the 2,700 level and to shorten the haul on the 2,700-foot level after these levels are connected.

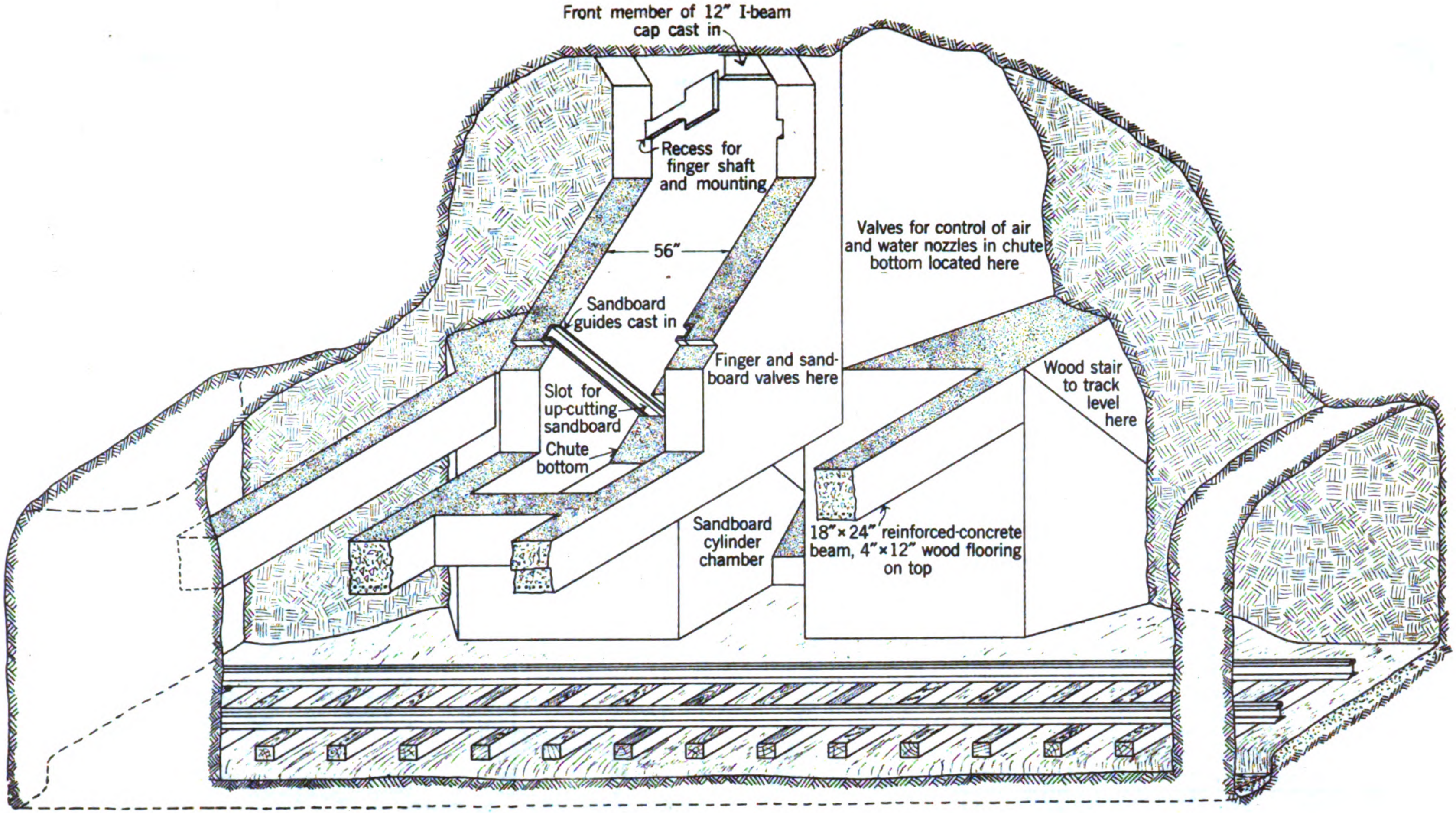
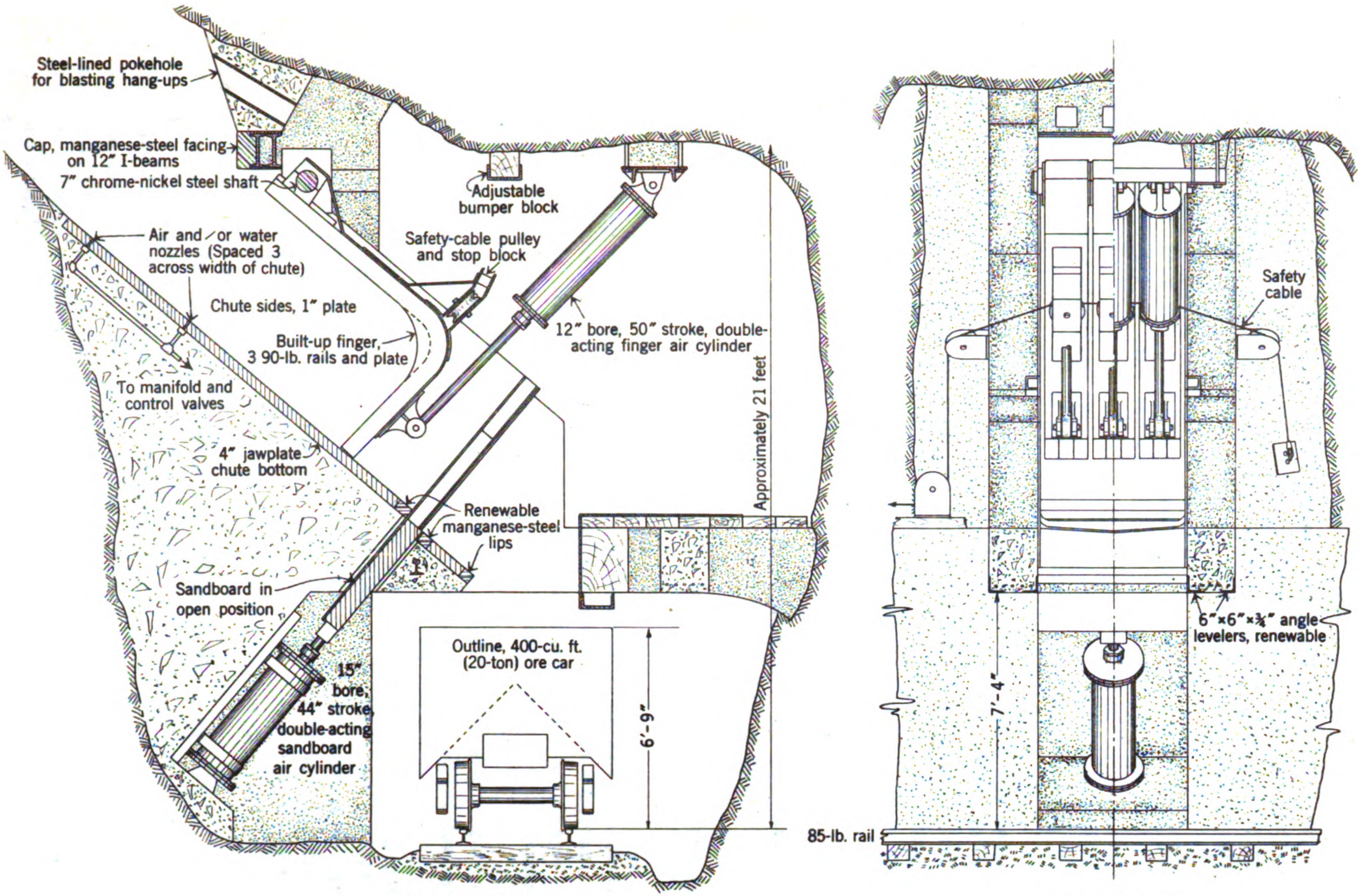

Front member of 12" I-beam cap cast in
Recess for finger shaft and mounting
56"
Valves for control of air and water nozzles in chute bottom located here
Sandboard guides cast in
Finger and sandboard valves here
Wood stair to track level here
Slot for up-cutting sandboard
Chute bottom
Sandboard cylinder chamber
18" × 24" reinforced-concrete beam, 4" × 12" wood flooring on top

Figure 19.—Layout of concrete work concrete loading chute as used on main haulage. (See fig. 20 for section on ℄ of chute and mechanical details.)


Steel-lined pokehole for blasting hang-ups
Cap, manganese-steel facing on 12" I-beams
7" chrome-nickel steel shaft
Adjustable bumper block
Safety-cable pulley and stop block
Air and/or water nozzles (Spaced 3 across width of chute)
Chute sides, 1" plate
Built-up finger, 3 90-lb. rails and plate
12" bore, 50" stroke, double-acting finger air cylinder
To manifold and control valves
4" jawplate chute bottom
Renewable manganese-steel lips
Approximately 21 feet
Sandboard in open position
Outline, 400-cu. ft. (20-ton) ore car
6'-9"
15" bore, 44" stroke, double-acting sandboard air cylinder
85-lb. rail
Safety cable
6"×6"×¾" angle levelers, renewable
7'-4"

SIDE ELEVATION

FRONT ELEVATION

Figure 20.—Details of main-haulage concrete loading chute. (See fig. 19 for concrete details.)

At present the ore is dumped in the Armour tunnel on the 2,700-foot level into 1 or 2 jaw crushers on the 2,800-foot level. These crushers reduce the rock to 5-inch cubes; they discharge into 2 raises in which there are observation points on the 3,100-foot level and control chutes on the 3,250-foot level. Below this point they join the main raise leading to the chute on the 4,100-foot level.

The ground is very wet and soft in places, and it was necessary to drive a "water raise" for drainage and to line sections of the raises with reinforced concrete and manganese-steel plates.

Main Haulage on 4,100-Foot Level.- The crushed muck, further broken by its long drop through the raise, flows perfectly, and under normal conditions loading on the 4,100-foot level is a swift and simple operation.

With very wet muck tremendous pressures are developed, which may cause serious spills at the chute. To prevent such spills, the flow of muck is carefully controlled by the control-chute operator, who is in telephonic communication with the trammers and the crusherman. Special attention, of course, is paid to keeping the raise drained as thoroughly as possible.

Details of equipment and operating conditions are as follows:

Cars:

17-ton hopper-bottom, manually operated type.

Locomotives:

One 18-ton Westinghouse trolley locomotive equipped with air brakes.

One 15-ton General Electric trolley locomotive equipped with air brakes.

Track:

36-inch gage, 80-pound rail; grade, 0.5 percent in favor of the load.

Power:

550-volt d.c.

Main Haulage on 2,700-Foot Level.- More than half the total mine production goes to the 2,700 level through No. 68 rock raise, which is therefore the most important drawing point. As a large part of the production comes from the gloryhole area, much water is encountered during the spring and fall, and special precautions against spills are necessary. The general haulage arrangement is shown in figure 5.

Control chutes are installed at the 2,200-foot, 1,800-foot, and 1,200-foot levels, and in wet seasons not more than 1 trainload of muck (sometimes less) is let down past the 2,200-foot level at one time.

A branch raise from the 2,700-foot level provides a second drawing point. The two chutes are connected by a circular track, so that trammers cannot be cut off in a dead end by a spill and so that a train buried by a spill may be cleared from either end or both.

Continual experience of the tremendous pressures exerted by wet and fluid muck led to the development of a monolithic reinforced concrete chute. (See figs. 19 and 20.) The construction is such that the chute can be bodily torn out before any part of it gives way, as the cap or posts of a timber chute do.

This chute has the following interesting operating features:

1. All the fingers may be operated together (normal conditions) or singly (wet conditions). Each of the fingers weighs 1,700 pounds.

2. The upcutting sandboard gives a sharp, clean cut-off with minimum spill. With this and the heavy, plated "levelers" a continually moving train can be loaded and the cars filled satisfactorily, thus avoiding the loss of time and strain on equipment caused by continually starting and stopping a heavy train to spot cars.

3. Air and water jets introduced under the chute bottom greatly facilitate the flow of sticky muck and reduce blasting.

4. Signaling is by means of a string of lights extending down the tunnel between the limiting positions of the motor in loading.

The tunnel is equipped with a block-light system, so that two 11-car ore trains and a nipping motor are operated safely over the same track.

Details of equipment and operating conditions are as follows:

Cars:

Twenty-six 20-ton A-frame cars equipped with air brakes. Doors are controlled by air cylinders operated from a quick-coupling hose. The doors are provided with safety catches operated by a hand lever so designed that the lever cannot slip into its slot unless the doors are properly closed and locked.

Locomotives:

Two 20-ton Jeffrey Manufacturing Co. trolley locomotives equipped with blowers to avoid overheating.

One 40-ton General Electric locomotive formerly used on surface and rebuilt in the company's shops to dimensions suitable for underground use.

Track:

36-inch gage, 85-pound rail; joints bonded; all frogs are manganese steel; ruling grade, 0.5 percent in favor of load.

Power:

550-volt d. c., return through rail.

Subsidiary Transportation.- Early practice was to draw muck from stope chutes and tram by hand or, later, by battery motor to rock raises. The present production, excluding that from the narrower, higher-grade veins of the Victoria mine, is entirely from bulldoze chambers. Rock-raise systems are often extensive, eliminating transfer chutes wherever possible. The present system, therefore, concentrates on drawing large tonnages from a few main chutes. All Fairview muck which cannot be drawn through wing raises into No. 68 rock raise is transferred on the 1,000-foot level. Extensive development of this level in the early days of the mine made it impracticable to lay out ideal haulageways for conditions now existing, so that it was necessary to adapt the old workings to present requirements. Track was relaid, with 45-pound rail, drifts widened, and drainage facilities improved. (See fig. 21.)

The chutes are of the finger-gate type with hand-operated sandboards. Signaling is by compressed-air whistles. (See fig. 22.)

Details of equipment and operating conditions follow:

Cars:

100 cubic feet capacity; these were designed and built in the Britannia shops. All cars are equipped with roller bearings. Considerable trouble was experienced with the first installation of these bearings, which did not stand up well, but this was almost entirely eliminated by smoothing out grades and curves in the track and by maintaining the track in first-class condition. These cars are illustrated in figure 23.

Locomotives:

6-ton General Electric trolley locomotives.

Power:

250-volt d. c. from a 150-kw. motor-generator set placed on the level.

Track:

24-inch gage, 45-pound rail; grade 0.5 percent in favor of load.

Production from the East Bluff section is trammed from 2 main transfer chutes on the 1,400-foot level to No. 68 rock raise under similar conditions except that only 1 train is in service.

The Victoria mine is developed through the No. 2 shaft. Ore is trammed by hand from the stopes and dumped into pockets at the shaft, whence it is hoisted to the 2,200 level by two 2 1/2-ton self-dumping skips running in balance and dumped into a storage raise. Thence it is drawn in 13-ton gondola-type cars, which are dumped by means of a compressed-air ram into No. 28 rock raise leading to a chute on the 2,700-foot level. (See fig. 5.) Four cars are in service, run by a 15-ton General Electric trolley locomotive. A daily production of about 400 tons is maintained.

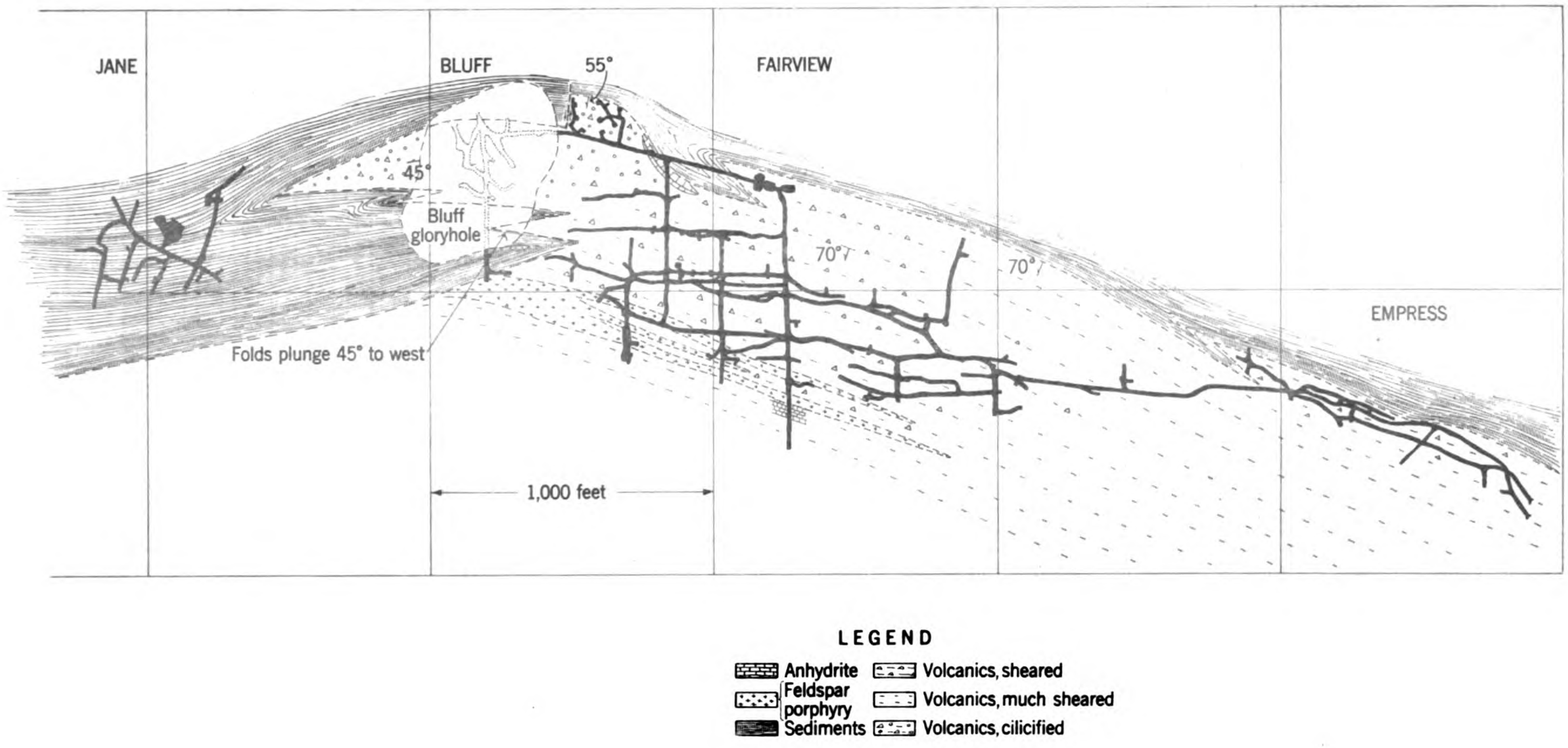


Figure 21.—1,000 level, geology and development.

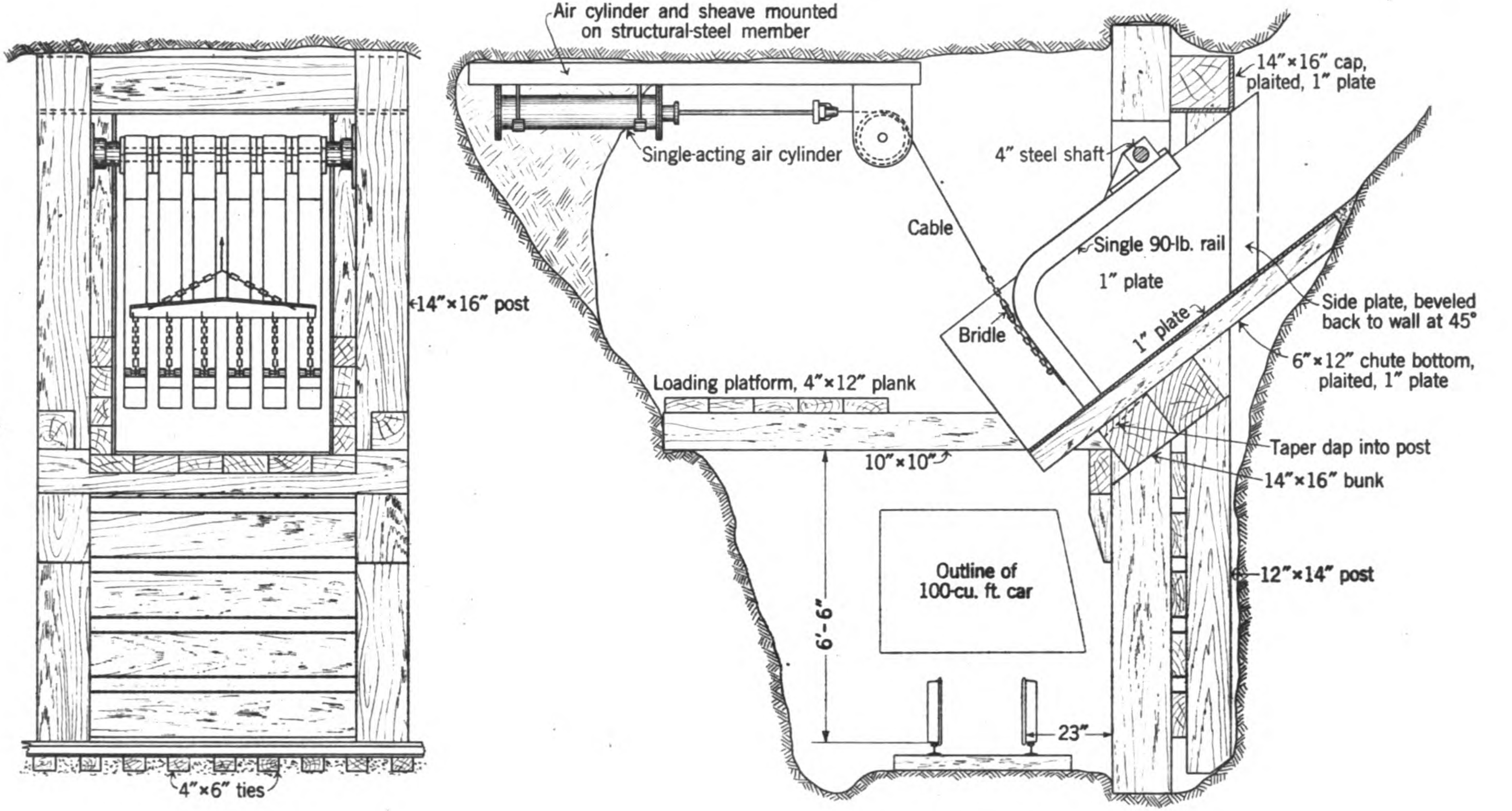
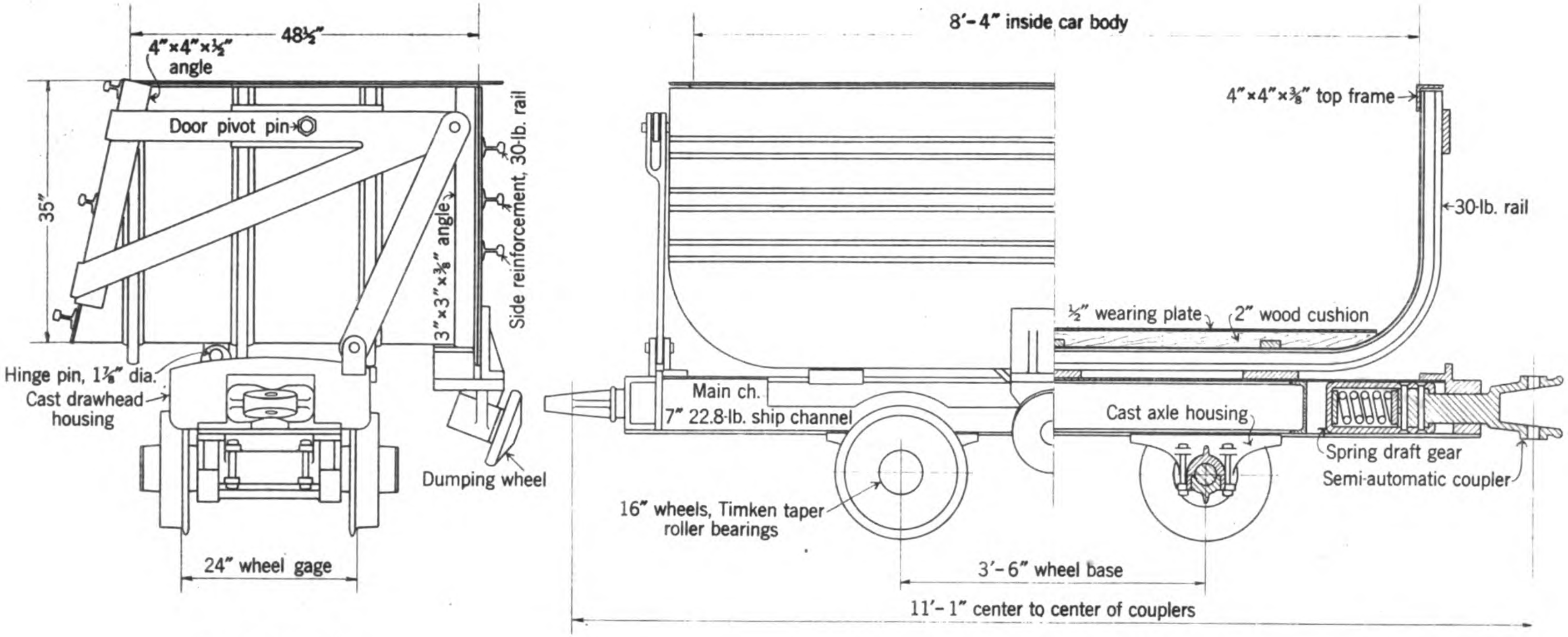

14"×16" post
4"×6" ties
Air cylinder and sheave mounted on structural-steel member
Single-acting air cylinder
4" steel shaft
Cable
Single 90-lb. rail
1" plate
1" plate
Bridle
14"×16" cap, plaited, 1" plate
Side plate, beveled back to wall at 45°
6"×12" chute bottom, plaited, 1" plate
Loading platform, 4"×12" plank
10"×10"
Taper dap into post
14"×16" bunk
Outline of 100-cu. ft. car
12"×14" post
6'-6"
23"

Figure 22.—Timber finger-gate chute as used on intermediate haulage levels with 100-cubic foot cars.



END ELEVATION

HALF SIDE ELEVATION AND SECTION

Figure 23.—100-cubic foot side-dump car for intermediate haulage.

The greater part of the production from the Bluff and West Bluff sections is handled directly by raises to the 2,700-foot level; some of it, however, is transferred to the 2,200-foot level. Thirteen-ton self-dumping cars are used in this section.

All track on the 2,200-foot level is 36-inch gage, 45-pound rail.

Freight Transportation.- Freight is hauled from the company's wharves by a 36-inch gage electric railroad to the foot of a single-track incline. One flat car at a time can be hauled up this incline by a 25,000-pound Allis Chalmers hoist run by a 150-hp. electric motor. The incline is approximately 6,000 feet long and rises 1,400 feet to the 2,700-foot level.

From the top of the incline an electric locomotive takes the freight over about 3 1/2 miles of surface railroad, rising 500 feet in this distance to the 2,200-foot-level portal, around which bunkhouses, shops, warehouse, etc. are grouped. The same cars can be taken into the mine on this level either to Victoria mine or to No. 1 shaft, which serves levels above 2,200 feet, or to No. 3 shaft, which serves levels below 2,200 feet.

Two 15-ton General Electric locomotives are used on the surface railroad.

MECHANICAL LOADING

Application

Mechanical loading at Britannia has been applied to two classes of work:

1. Mucking development rounds:
    - (a) Main haulage-tunnel extension, employing the larger types of mucking machine.
    - (b) A few headings of intermediate size.
    - (c) Shaft-sinking - a semimechanical application.
2. Transferring stope muck:
    Handling broken muck from stope drawing points to transfer raises.

History

The first major work with mechanical loading equipment was done in the 2,200-level haulage tunnel driven in 1923-24; this connects the Fairview and Victoria workings. In this tunnel, which is 9 by 8 feet in the clear, an early type of nonportable scraper slide built of an angle-iron framework bolted to column bars was tried out. This was followed by two types of Armstrong Butler Shuveloders, a Conway electric shovel, and finally by a locally built portable scraper slide described later.

In sinking the Victoria No. 2 shaft semimechanical loading was practiced on a system which has been successfully used at the United Verde and elsewhere. Muck was scraped with shovels into a flat pan which was lifted by a small tugger hoist and dumped into a mine car carried on an extension platform below the cage. This system eliminates the hardest work of shoveling, that is, the direct lifting of the load on the shovel. In the work here, particularly at Victoria, having the muck in a car greatly facilitates its disposal as waste filling.

In 1931 two 35-hp. double-drum (type HDE 35) electric hoists were purchased to transfer broken ore short distances by slushing. Such good results were ultimately obtained from this equipment that one of them was mounted on a locally designed and built portable scraper slide for advancing the 4,100-level haulage tunnel. This proved a great success. These installations are now regarded as standard practice.

4,100-Level Haulage Tunnel

This tunnel is 10 by 12 feet and was advanced 1,497 feet during 1932. A portable scraper slide was used for all mucking; it was mounted on four wheels and equipped with a coupling at the rear so that it could be pushed to the muck pile by the train of empty cars and was designed to load into 120-cubic foot cars. A 35-hp. hoist handling a 48-inch scraper was used.

After 2 or 3 experiments a standard hoe-type scraper was found best suited to the rather chunky muck encountered. A replaceable manganese-steel lip is an important feature of its construction. This scraper handles 1,600 to 1,800 pounds of muck at each pass and when set up as usual, about 25 to 30 feet from the face, has an actual loading rate of about 2 tons per minute. Cars are switched on an O'Rourke car switcher; the gross loading rate, including switching, is 60 to 70 tons per hour.

Ample electric lighting is provided on the scraper slide so that the operator works under the best possible conditions.

The tail sheave is hung on a chain stretched across the face, attached to Lewis wedges driven into holes drilled for the purpose. It can thus be quickly moved from side to side.

Figure 10 is a drawing of the scraper slide; more detailed information may be found under 4,100-Foot Level Haulage Extension.

This machine proved to be a very fast mucker, much lower in first cost than any shovel-type machine of equal capacity, simple to operate, and extremely reliable. An occasional broken cable is about all the mechanical trouble to be expected.

Slushing from Stopes

Considerable experimental work was done on the 600 and 850 levels in slushing ore from drawing points under the stopes to transfer raises.

A 35-hp. hoist was again used, this time handling a 60-inch hoe-type scraper of about 2 tons capacity. Ore was fed on to the sill through a chute, the height of the muck pile being so regulated that the scraper could easily pass it on its return trip.

A bed for scraping was made by laying worn-out 45-pound rails side by side the full width of the drift. This, by eliminating the wear on the scraper and the frequent spilling of part or all of the load characteristic of hauling over rough bottom, has proved of great importance.

Ample illumination is provided by electric lights, as good visibility is very necessary for efficient control of the scraper.

Rate of loading, of course, varies with the type of muck handled, the presence of large boulders, and hence the rate of flow through the chute, the chief determining factor. The actual rate of loading muck after it is drawn from the chute is 1 1/2 to 2 tons per minute.

The latest installation is a 75-hp. double-drum electric slusher hoist, capable of handling a 5-ton scraper; this was used with great success for removing overburden from above the East Bluff orebody prior to gloryholing. It will now be used for transferring ore underground.

Hoisting Practice

The Victoria shaft and No. 4 shaft are the only ones through which ore is hoisted. At the Victoria shaft pockets, each holding 70 to 100 tons, are placed on alternate levels. Air-operated finger gates at the loading pocket discharge into loading hoppers holding 50 cubic feet. The loading hoppers discharge through air-operated down-cutting knife gates

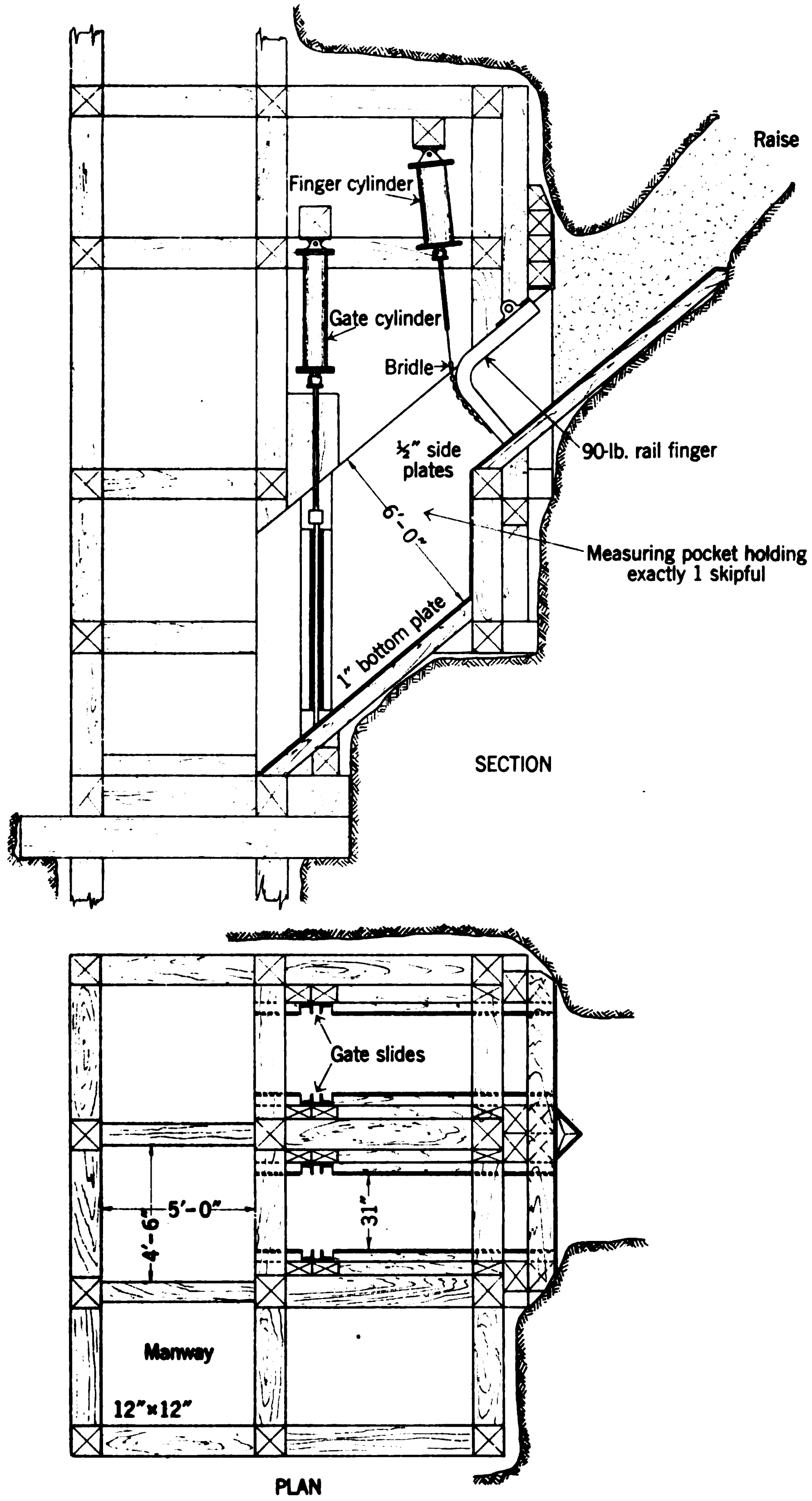
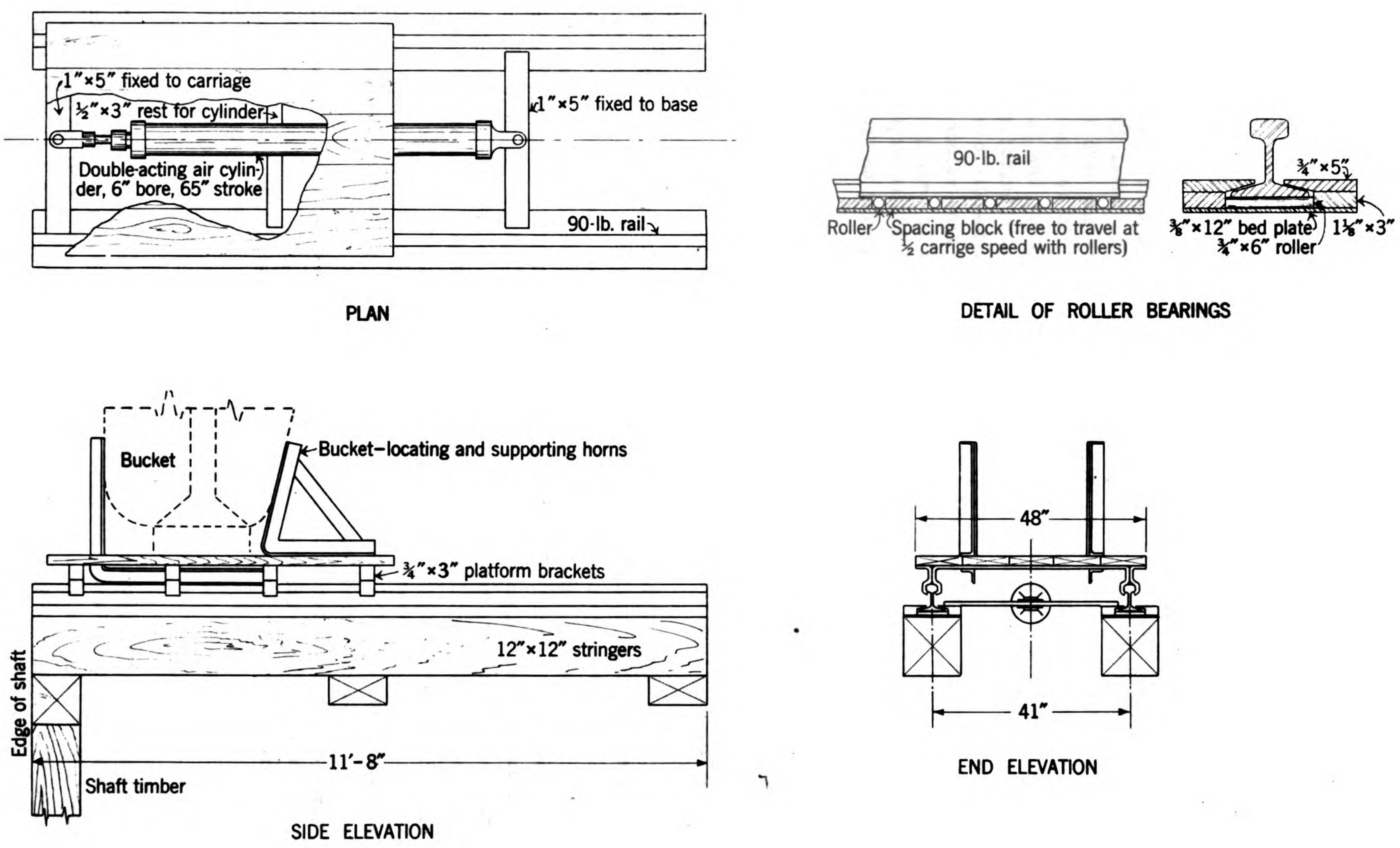


Figure 24.—Loading equipment, Victoria shaft.



PLAN

DETAIL OF ROLLER BEARINGS

SIDE ELEVATION

END ELEVATION

Figure 25.—Bucket changer, Victoria shaft.

directly into 50-cubic foot skips (see fig. 24). The skips are fastened below the mine cage by extension bolts and a 2-inch shackle pin. When not in use for hoisting they are removed on the 2,100 level to a special carriage which extends into the shaft for this purpose. (See fig. 25.)

The ore is hoisted to a midshaft pocket above the 2,100 station. This pocket holds approximately 300 tons and discharges onto the 2,200-adit level through up-cutting, air-operated knife gates. The ore is trammed in 13-ton gondola-type cars to main transfer raises leading to the 2,700 level.

From the level over the shaft pocket a transfer raise is run to the level above. This raise provides storage of 300 to 400 tons and at the same time eliminates the expense of another shaft pocket and the unnecessary opening up of heavy ground around the shaft. The transfer raise discharges through arc-gate control chutes into the shaft-pocket grizzly. These grizzlies are of 100-pound rails with 11-inch spaces.

No. 4 shaft handles only development muck. Production from this area will be handled direct through rock raises to the extension of the 4,100-foot-level haulage tunnel. The ore is hoisted in a 2 1/2-ton skip, unbalanced, and dumped into an 80-ton pocket, from which the muck is drawn through an air-operated finger-gate chute into the standard 20-ton cars on the 2,700-level tunnel.

Percentage of Extraction

In the filled stopes of the Victoria and Empress mines dilution, of course, is negligible; the Empress uses filled stopes almost exclusively. Virtually 100-percent extraction is obtained.

In the Upper Fairview section dilution is considerable owing not only to the normal caving from the hanging wall but also to the necessity of blasting down some waste with the ore by coyote-hole methods. The actual recovery of ore, however, is high. The essential point is to maintain the highest drawing points on the footwall as long as possible and to draw from them all the ore possible before moving to a lower level. If the drawing point is moved down too soon and drawing from it is continued, the hanging wall may cave and cut off the broken ore above and at the same time the sill above caves and the drawing point is lost.

In the hard ground of the East Bluff the walls stand well; under a systematic method of mining and drawing most of the ore is recovered, and losses here will not exceed 10 percent. The Britannia mining method has been used throughout this section.

The poorest extraction is obtained in the West Bluff. The softer hanging wall caves readily and may dilute the ore to such an extent that the mixture is below commercial grade before all the broken ore can be drawn from the stope, as in certain sections where the footwall is very flat and the dip is only 45°. In such instances the usual plan of recovering the lost ore by means of sublevel drawing points in the footwall is rendered difficult at Britannia by the soft nature of the footwall itself.

Power

Part of the power used at the property is generated locally in the company's own power houses, and part of it is purchased; any excess required above the company's own generating capacity is obtained from the power company serving the lower mainland of British Columbia.

Precipitation on the watershed area supplying water for power purposes ranges from a low of about 2 1/2 inches per month in June and July to around 14 inches in December, with approximately 300 inches of snow. Total precipitation at the mine averages 85 inches per year. Close check is kept on the amount of water in the storage dams, and every effort is made to conserve this as much as possible and yet not lose more than necessary at flood periods. This control not only enables the company to obtain a maximum amount of power over the year from the rather limited storage facilities available but also smooths out peak loads on the public-utility company's lines.

At the mine powerhouse (elevation, 2,100 feet) are two trolley M-G sets, air compressors with a total capacity of over 14,500 c.f.m., together with distribution and control switchboard and associated apparatus. The compressed-air production is divided between the following units: Two 3,500-c.f.m. Ingersoll-Rand two-stage compressors direct connected to 160-r.p.m. Pelton wheels working under a 1,500-foot head; one 3,500-c.f.m. Ingersoll-Rand two-stage compressor direct connected to a 500-hp., 150-r.p.m., 6,600-volt synchronous motor; two 1,500-c.f.m. Ingersoll-Rand two-stage compressors belted to 600-r.p.m. motors; one 750-c.f.m. Ingersoll-Rand two-stage compressor belted to a 100-hp., 450-r.p.m. motor.

The switchboard and switchgear are of the latest Westinghouse remote-control, metal-clad type. This equipment is housed in a 113- by 55-foot galvanized-iron building at the 2,200-level portal.

The beach powerhouse (elevation, 200 feet) uses water from a storage basin under a 1,700-foot head on Britannia Creek just below the tunnel powerhouse tail race and from a diversion dam under a 700-foot head on Furry Creek. Here are located: One 2,500-kva direct-coupled, pelton-driven, 6,600-volt generator operating on a 700-foot head from a diversion dam at South Valley in Furry Creek; one 2,500-kva direct-coupled, pelton-driven, 6,600-volt generator operating on a 1,700-foot head from the dam near the tunnel powerhouse on Britannia Creek; one 2,500-kva direct-coupled generator driven from a pelton wheel working on both of the above-mentioned pipe lines; 3 electric air compressors; one 3,600-c.f.m. Ingersoll-Rand machine of the same general type as that at the tunnel powerhouse; one 1,250-c.f.m. Ingersoll Rand machine of similar design; one 750-c.f.m. belt-driven machine; and 3 motor generator sets. The tail race from this powerhouse is used to supply water to the mill.

All power with the exception of trolley d. c. and a small amount generated for auxiliary purposes is produced at 6,600 volts. Secondary distribution is at 440 volts.

Compressed air is delivered from the tunnel powerhouse compressors to receivers at the mine portal after passing through aftercoolers. The coolers have a separate cooling-water supply derived from a small diversion dam up Britannia Creek. The beach and mine receivers are connected by an 8-inch line, allowing either powerhouse to boost the pressure at the other end as occasion demands.

MINE DRAINAGE AND COPPER PRECIPITATION

The upper section of the Fairview orebody has been intensively gloryholed; considerable subsidence has also taken place, resulting in a large area of broken, low-grade sulphides. Water from a catchment basin of about 40 acres on Britannia Mountain, where the annual precipitation is nearly 100 inches, percolates through this caved zone, leaching out considerable copper in its passage downward into the mine. This water is sampled periodically at the various points where it enters the mine workings and is routed, according to its copper content, either into waste channels or to a flume on the 2,200-foot level leading to a precipitation plant at the portal. The flow to the precipitation plant varies with the seasons — between 6,000 and 40,000 gallons per hour. The assay value ranges from 0.6 to 2.0 grams of copper per liter, the tendency being to increase with increasing flow. The following is a typical assay of precipitation-plant heads:

	Grams per liter
Copper..................	0.98
Ferrous iron............	.17
Ferric iron..............	1.61
Free sulphuric acid	.023

The copper is in solution as copper sulphate.

The precipitation plant comprises 37 tanks, each having two 5- by 5- by 5-foot compartments. Tanks are of cedar; no metal is used in their construction. They have inclined floors, above which is a wooden grating which supports the scrap iron used as a precipitant. Agitation is effected by low-pressure air introduced through perforated lead pipes placed below the gratings.

The pregnant mine water, after passing through settling tanks, is agitated in the precipitation tanks in the presence of shredded scrap iron or tin cans; 95 percent of the copper is precipitated in 55 minutes of exposure. Periodically this copper sludge is flushed out of the tanks, dried, sacked, and shipped to the smelter. The sludge as shipped averages 67-percent copper. The total direct cost of production is 2.14 cents per pound of copper. Production from the precipitation plant averages 1,200,000 pounds of copper annually.

Certain metallurgical disadvantages are inherent in a plant of this type as compared with the straight launder type common in the Southwestern States, notably limitation of the type of precipitating medium; but the very low ratio of space required to plant capacity more than compensates for this, especially in a section where a very heavy snowfall must be handled.

The cupriferous water is naturally very corrosive and quickly attacks pipe lines and rails. Protection of these is an important feature of mine drainage. At the Victoria mine the mine water is passed through a small precipitation plant before it reaches the pump to prevent corrosion of cylinders and plungers.

BONUS PRACTICE

History

The bonus system has materially lowered the costs of operations to which it could be applied.

With the establishment of a special bonus department involving a detailed set of records and a system of bonus payments above the regular wage scale on increased amounts of work one of the most important phases of the whole question of labor-cost reduction has been placed on an engineering basis.

General Principles

The basis of this, as of any bonus system, is the fixing of standards of performance for given working places, followed by the payment at a fixed rate for work done in excess of the standard. This rate is usually such that the saving is distributed equally between the company and the men.

Standards are published on bulletin boards before work is commenced; statements of performance and earnings are similarly published as soon as possible after they are calculated. Bonus is paid at least once a month and, when possible, twice a month, according to the frequency of the engineer's measurement.

Where conditions are to be improved by change of equipment, better ventilation, etc., the men are warned beforehand that their standard will be raised when the change takes place.

Limitations

It should be pointed out that local conditions restrict the application of any system of extra payment in certain important classes of work and thus create a special problem that requires careful handling.

Chutes and Bulldoze Chambers.- In the handling of broken ore from stopes and gloryholes tramming on intermediate levels has been eliminated in some areas and greatly reduced in all others by systems of wing raises feeding ultimately into the main rock raises. Thus, all the ore from the present productive area above the 500-foot level, where 7 or 8 bulldoze chambers are active every month, is mixed in one transfer raise before it reaches the 1,000-foot level, where it is trammed into a system of raises all feeding a chute on the main haulage level at the 2,700-foot level; here it is again mixed with ore from several other working places.

There is thus no reliable check on the tonnage coming from individual working places, and the cost of car tally by special men would be prohibitive. The only possible form of bonus payment would therefore be a "group bonus" embracing all working places feeding into each main rock raise; this has been found unsatisfactory. The group is too large, and the individual's part in it is so small that he does not feel the direct incentive that is the aim of any bonus system.

Large Stopes.- In large shrinkage stopes conditions of breaking are variable, and the extent of caving cannot be foretold exactly. By producing a broken tonnage often quite unrelated to the efforts expended by the miners caving renders bonus payments undesirable for this class of work. With the increasing use of the Britannia method this type of stope, except in the undercutting stage, is virtually nonexistent.

For these reasons, supported by the results of considerable experiment, no bonus is paid in such classes of work. Although each restriction of the application of bonus payments is in itself undesirable, as tending to create dissatisfaction, it is believed in this instance to be the lesser evil.

Applications

The following classes of work have been found eminently suitable for the bonus or contract systems of payment.

Development.- Drifting and crosscutting, sinking, and raising are all paid for on a basis of a set rate per foot above the set standard or, more often, on a straight contract basis of so much per foot.

Narrow Stopes.- Square-set and cut-and-fill rill stopes are used in the Victoria mine, whereas narrow shrinkage stopes are used on the lower levels of the Fairview mine. Square-set stopes are paid for on a basis of tonnage broken, measured by counting the number of sets placed, rill stopes on tonnage from surveyor's measurement; and shrinkage stopes either on tonnage or on area of footwall exposed. The latter method is preferred, being a truer measure of effort expended, in stopes where the width vein varies considerably, yet within limits that permit the breast to be broken with the same number of holes. Also, the average miner can understand this system when properly explained to him and can visualize the results of his day's work better than he can under the broken-tonnage system.

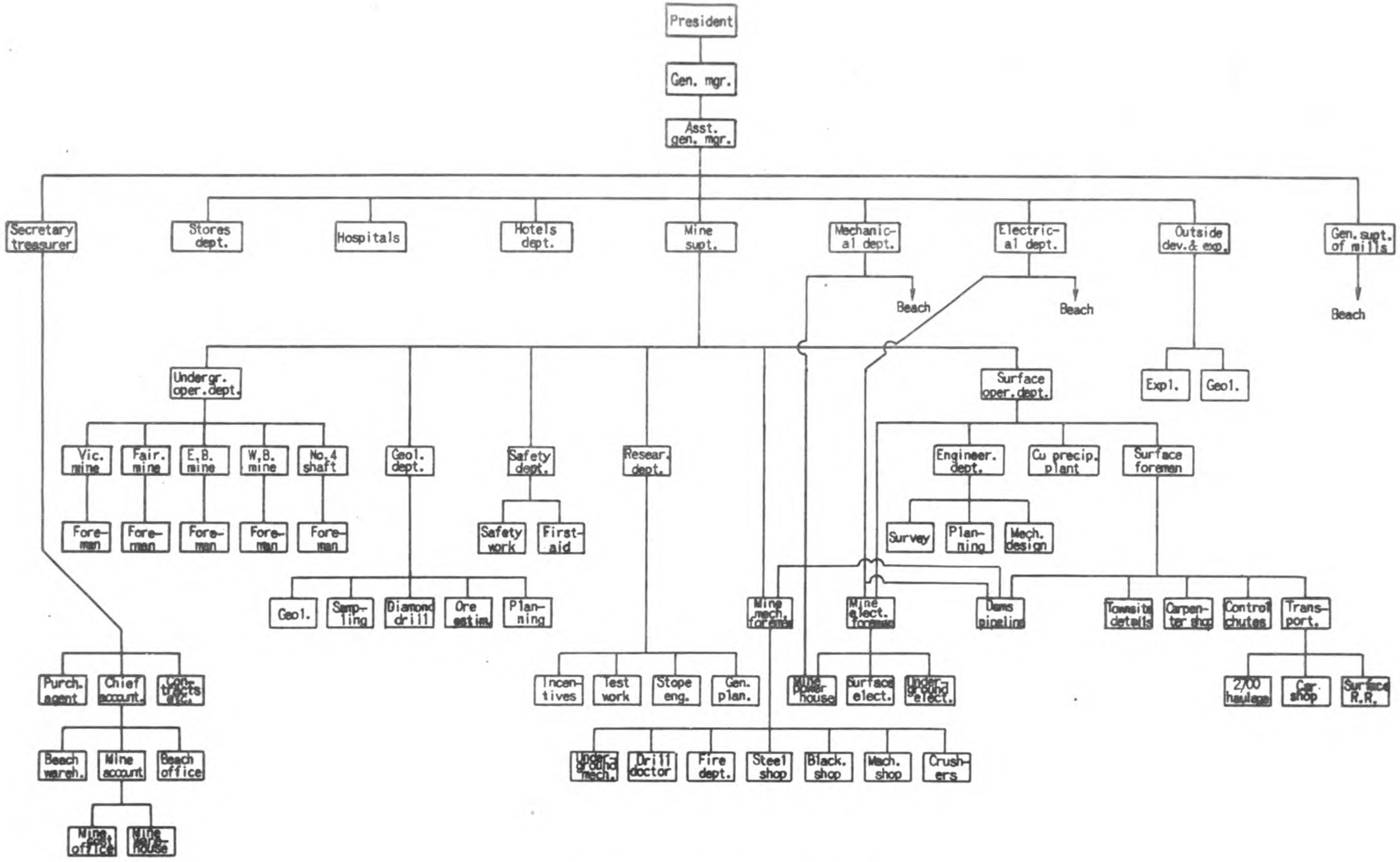


Figure 26.- Organization chart - mine department.

Backfilling.- Trammers handling waste filling to stopes are paid bonus based on the calculated volume of filling dumped.

Special Work.- Special jobs of timbering or excavation may be put on contract if all conditions are suitable.

Bonus or Contract

The essential difference between bonus and contract is that in the first case the company always receives a definite proportion of all saving in cost, usually one half, whereas in a contract the labor cost to the company is fixed, and all profit beyond that determined by the contract price goes direct to the contractor.

Although the bonus system thus acts as a safeguard in "runaways", which present unexpectedly favorable conditions, yet in most cases the difference is more apparent than real. If the preliminary estimating is properly done, about the same results in cost per foot can be obtained from the two systems.

For example, during a period of intensive stope development a large number of wing raises had to be driven. A number of these were driven on bonus, and for a total footage of 1,464 the average labor cost was $5.45 per foot. Later, another series of these raises was driven on contract at $5.50 per foot, and the miners made satisfactory profits.

In general, contract work gives higher speed because beyond a given point the profits to the miners increase more rapidly than under the bonus system; it is therefore preferred where speed is of value in itself.

Explosives

Conditions at Britannia do not favor the practice of including explosives in contract prices. The relatively large quantities of powder required to be kept available adjacent to bulldoze chambers militate against this practice.

Other Bonus

Shift bosses are paid a "performance bonus" based on the performances of their crews. This provides an incentive for them to facilitate the work of men on bonus, with consequent lowering of costs. They also receive bonuses for good safety records.

Organization

The bonus department is a branch of the research department, which carries out all experimental work underground and keeps all records relating to performance and efficiency. The personnel of this department varies according to conditions.

Most of the routine office work is divided between the mine engineering office (records of footage, tonnage, etc.) and the mine time office (records of bonus labor). The bonus engineer is thus free to spend most of his time underground keeping in touch with the working places, the crews, and the mine bosses and the remainder, in working up standards for new jobs.

Young graduates or students are often requisitioned from sampling or work in the mine for making time studies.

The bonus engineer calculates bonus payable twice each month, sees to the publishing of results, and posts the amounts payable for the timekeeper. The men receive their bonus payments on the first pay day following completion of the period for which settlement is made.

Figure 26 is an organization chart of the mine department.

VENTILATION - NATURAL AND MECHANICAL

The natural ventilation throughout the mines is good during most seasons and is generally adequate. Occasionally it is necessary to assist the natural draft by means of doors and bulkheads, and sometimes artificial ventilation is required.

Natural Ventilation

Preference to fig. 5 indicates the freedom with which natural air currents can pass through the mine, between the many gloryholes from the 250 level downward, and the main haulage tunnel at the 2,700 level. The natural draft is seasonal. In cold weather, usually October to May, inclusive, the underground workings are much warmer than the outside air, causing an upward movement of air through the mine openings and a very strong inward current on the two lower adits, the 2,700 level and the 2,200 level. During the hot summer months these air currents are reversed.

Assisted Natural Ventilation

At times, it has been necessary to confine the natural draft, whether upcast or downcast, to particular areas by means of ventilation doors. This method was used with success in the upper Fairview mine, where the old workings were so extensive that the air current split up into many separate flows too small to supply enough fresh air to the working places.

In another form the method has been of great service in the Victoria mine, where the main shaft is a natural downcast at all times. This mine differs from the others in that all main workings are now below the adit level. Doors at the shaft stations on each level direct the full downcast current to the lowest level, which is connected to the upper levels by raises. From here it rises through the workings. Open manways are maintained through old stopes to permit free passage of the foul air rising above the main working levels.

Artificial Ventilation

Until quite recently the use of fans has been unnecessary except in long development headings. The working of the East Bluff mine, however, has caused very smoky conditions on the bulldoze-chamber levels, the gloryholes having become filled with muck above the levels of the portals. The ventilation of bulldoze chambers on the 1,000 and 1,200 levels in this section has therefore become a major problem, complicated by the fact that the necessary adaptation of old workings to the scheme of East Bluff development has produced a lay-out of service drifts not well suited to the requirements of a system of artificial ventilation.

On a level on which five or more bulldoze chambers are active, each using an average of 50 pounds of 40 percent forcite per shift, it is impracticable to ventilate the workings by a through current of air, as the smoke from one or more workings is thereby drawn through the others. The only method found satisfactory is to blow the smoke out of the B.D.C. into the service drift and there pick it up by a fan-pipe extension.

A branch fan line serves each bulldoze chamber, and the air is exhausted by a Sirocco fan to some suitable point where the natural draft will dissipate it through nonworking sections of the mine.

To clear the bulldoze chamber rapidly of smoke, a hole is drilled through the wall and an air pipe inserted in it so that compressed air may be blown inside the chamber without having to maintain a pipe-line there which would be damaged by blasting. Where this is not possible a line is run through the B.D.C. buried under the muck, and an air jet is placed in the refuge chamber. Both methods are shown in figure 27.

FIRE HAZARDS

The low temperature, dampness, and free ventilation of most of the mine and the noncombustible nature of the ore, combined with the relatively small extent of timbered workings, render the mine singularly free from natural fire hazards. Care is taken, however, to see that no inflammable rubbish accumulates underground. The following rules are strictly enforced:

1. No inflammable material is allowed to accumulate, even temporarily, within 10 feet of a powder magazine or fusehouse.
2. Proper containers for waste, oil, and gasoline underground are used.
3. All trash must be cleared up daily; it must either be taken out of the mine or dumped in dilute proportion in the waste-filling of old stopes.

Pyrene extinguishers are provided in underground hoist rooms and shops.

The mine is protected from fires, which might start in buildings near the portal on the 2,200-foot level, by heavy fire doors in the tunnel.

SAFETY METHODS

The safety organization is in charge of a safety engineer, and the problem is approached as follows:

1. Safety program.

(a) Detailed records of accidents are maintained and the causes analyzed, so that the causes of the more common types of accident may be fully understood and remedial measures taken.

(b) Working conditions are studied carefully with a view to eliminating hazards.

(c) Protective devices are fully investigated and tested.

2. Safety propaganda.

It is recognized that safety is largely a matter of education, and hence a constant educational campaign is carried on:

(a) Safety meetings are held every 2 weeks on the company's time for each level in the mine and for each convenient group of surface employees, at which the freest discussion is encouraged. The experience in accidents and accident prevention of each department is thus brought to every other department. Suggestions from workmen are encouraged.

(b) A varied display of safety notices and posters on neat and well-lighted bulletin boards is used to maintain interest. Posters from the National Safety Council are supplemented by home-made signs of topical interest.

(c) Large, simple, accident-record charts are published to compare the records of different mines and shifts and encourage the competitive spirit. Shift bosses are encouraged by a system of safety bonuses for good records.

(d) The use of certain protective devices, such as the hard hat in general work and the safety belt and rope in bulldoze chambers, is compulsory. The use of gloves by men handling rocks, cables, or other material which may cause lacerations and subsequent infections and the use of hard-toed shoes by all men is urged. Goggles and dust respirators are issued without charge to all workmen requiring them.

First-Aid Organization and Training

First aid not only minimizes the effects of injuries received but also reduces their number by creating a "safety-minded" attitude. It has been found that men well trained in first-aid are seldom victims of easily preventable accidents.

The training work is carried on under the auspices of the St. John Ambulance Association. There has been no lack of volunteer instructors from the men themselves. Classes are held each winter, and the examinations are followed by an indoor meet, with contests and demonstrations followed by a dance. A cup is donated for yearly competition by the company.

Training has now been extended to include classes for the women and children of the community.

In the mine each shift boss is required to have a team of four first-aid men whom he can quickly assemble at the scene of any serious accident. First-aid kits are placed at a number of points, and basket stretchers, blankets, and sets of splints are kept at all hoist rooms. As soon as news of an accident is received at the shaft the hoistman telephones to the hospital, arranges for a locomotive, and clears the cage for the injured man. Transportation to the company's hospital is thus both rapid and under proper conditions.

Cooperative Store

Instead of the local stores being run as company organizations, they are run as purely cooperative ventures.

The store manager is selected by the company. At both the mine and beach town sites committees are elected annually to advise the store management as to the running of the various stores and to act as liaison officers in investigating any complaints that may arise.

All purchases made by employees are recorded whether they are for cash or on credit. At the end of each 6-month period dividends are paid to every employee who has been on the pay roll for 3 months preceding the dividend period; such dividend bears the same ratio to the total profit made during the 6-month period as his purchases bear to the total purchases of all employees during that period.

No dividend has ever been passed, and they have ranged from a low of 1 3/4 percent during the depression to a high of 16 percent. The arrangement has been very satisfactory to all concerned.

Free Group Insurance

In 1926 a system of free insurance was inaugurated. Since then the payments from this insurance have been of very great assistance to many people here. As soon as an employee has been on the pay roll 6 months a policy for $500 is made out and sent to him. Thereafter at the end of each 6-month period a further sum of $200 is added to the policy until at the end of 3 years a total of $1500 is carried for him entirely by the company.

If at any time the employee severs his connection with the company, he is allowed to take out any standard form of policy for himself without medical examination.

Amusements

Two motion-picture shows are operated, one at the beach and the other at the tunnel camp; pictures are shown once or twice weekly. The dramatic club usually puts on 1 or 2 productions during the season.

A large part of the amusement organization is under the direction of the mine social club, a monthly fee being assessed by the men themselves to keep up this organization. A motion-picture theater, a large gymnasium, club, library and reading room, and pool-room space are provided by the company. A president and an executive committee are elected every 6 months, and chairmen for the various social activities are chosen from these executives. They are in charge of dances, card parties, baseball, softball, roller skating, hockey, basketball, swimming, and other social activities of a general nature. A fully equipped gymnasium also comes under the management of the club; here roller skating, badminton, basketball, and dances are held. There are four double tennis courts at the tunnel camp, and much enthusiasm is shown for the game during the summer months. A ski run and a short jump was constructed last summer, and full advantage was taken of it this winter, many taking part in this sport for the first time during the past winter.

The library and reading room also come under the jurisdiction of the social club. A library of over 3,000 volumes and a reading room complete with daily papers, weekly and monthly periodicals, and magazines are open for the use of all club members and their families.

The first of July is celebrated annually at the mine as a big sports day. All the usual children's and adult's races and drilling and mucking contests are held. The late afternoon is usually given over to water sports in the swimming tank, swimming and relay races, diving, and water polo being the main events. Sports day ends with a dance.

Christmas is also celebrated for the children. The entertainment takes the form of a Christmas-tree celebration, with presents delivered by Santa Claus, followed by a supper.

SUMMARY OF COSTS

East Bluff mine; 12-month period.
Ore hauled during period, 398,664 tons.
Mining method, Britannia.
Underground costs per ton of ore hauled:

	1	2	3	4	5	6	7	8
	Labor	Supervision	Compressed-air drills and steel	Power cost	Explosives	Timber	B.D.C.	Total
Development	0.024	0.005	0.009	0.005	0.022	0.015		0.080
Mining	.055	.013	.010	.010	.088	.016	.043	.235
Tramming	.025	.006		.020	.009			.060
General underground expense	.056	.013						.069
Surface expense (directly applicable to underground operation)[2]	.057	.013						.070
Total	.217	.050	.019	.035	.119	.031	.043	.514

[1] Includes track, drainage, level maintenance, hoisting, and sampling.
[2] Includes geology, surveying, assaying, office and warehouse, and workmen's compensation.

This piece of ground is very highly silicified and is exceedingly hard and abrasive. Because of this hardness the bulldoze-chamber openings have been reduced to 24 inches; therefore many holes and a great deal of powder are required in both the primary and secondary breaking.

Victoria mine; 12-month period.
Ore hoisted during period, 133,195 tons.
Mining method, Square-set.
Underground costs per ton of ore hoisted:

	1 Labor	2 Supervision	3 Compressed-air drills and steel	4 Power cost	5 Explosives	6 Timber	7 Filling	8 Total
Development	0.062	0.005	0.009	0.013	0.022	0.020		0.131
Mining	.462	.030	.054	.071	.126	.113	.275	1.131
Tramming	.121	.013						.134
General underground expense[1]	.142	.009		.024		.037		.212
Surface expense (directly applicable to underground operation)[2]	.144	.016						.160
Total	.931	.073	.063	.108	.148	.170	.275	1.768

[1] Includes track, drainage, level maintenance, hoisting, and sampling.
[2] Includes geology, surveying, assaying, office and warehouse, and workmen's compensation.

Fairview mine; 12-month period.
Ore hauled during period, 1,268,234 tons.
Mining method, combined Britannia and gloryholing.
Underground costs per ton of ore hoisted:

	1 Labor	2 Supervision	3 Compressed-air drills and steel	4 Power cost	5 Explosives	6 Timber	7 Total
Development	0.004	0.001		0.002	0.001		0.008
Mining	.112	.008	0.003	.018	.008	0.012	.161
Tramming	.043	.003		.030	.001		.077
General underground expense[1]	.033	.002					.035
Surface expense (directly applicable to underground operations)[2]	.032	.003					.035
Railroad to mill	.053	.001					.054
Total	.277	.018	.003	.050	.010	.012	.370

[1] Includes track, drainage, level maintenance, hoisting, and sampling.
[2] Includes geology, surveying, assaying, office and warehouse, and workmen's compensation.

East Bluff, Britannia method.

Labor, man-hours per ton:

	Development	Mining
Bulldozing		0.064
Breaking	0.022	.020
Timbering		.012
Muckers	.012	.042
Trammers		.027
Hoistmen		.017
Supervision	.006	.012
General	.007	.026
Total underground	.047	.220
Average tons per man-shift	0.46	36.18
Labor, percent of total cost	9.89	45.71
Powder, pounds per ton	.15	.61
Timber, F.B.M. per ton	.13	.52

	Kw.-hr. per ton
Power:	
Air-compression	5.60
Hoisting	.54
Pumping	.18
Ventilation	.23
Lighting	.04
Total	6.59

	Cost per ton
1,050 Level Tramming:	
Direct labor	0.014
Direct supplies	.002
Miscellaneous underground tramming, labor and supplies[1]	.030
Total	.046

	Cost per foot
Victoria No. 2 Shaft:	
Labor	38.27
Explosives	6.19
Timber, air, sharpening, etc.	20.09
Total for 212 feet in 1931	64.55

[1] Includes control-chute labor and supplies, track, chute repairs, car and locomotive repairs, and general overhead expense.

	Cost per foot
Victoria No. 4 Shaft:	
Labor	27.57
Explosives	7.90
Timber, air, sharpening, etc.	22.73
Total for 245 feet in 1931	58.20
Wages:	
Miners	5.25
Jigger bosses	5.75
Hoistman	5.00

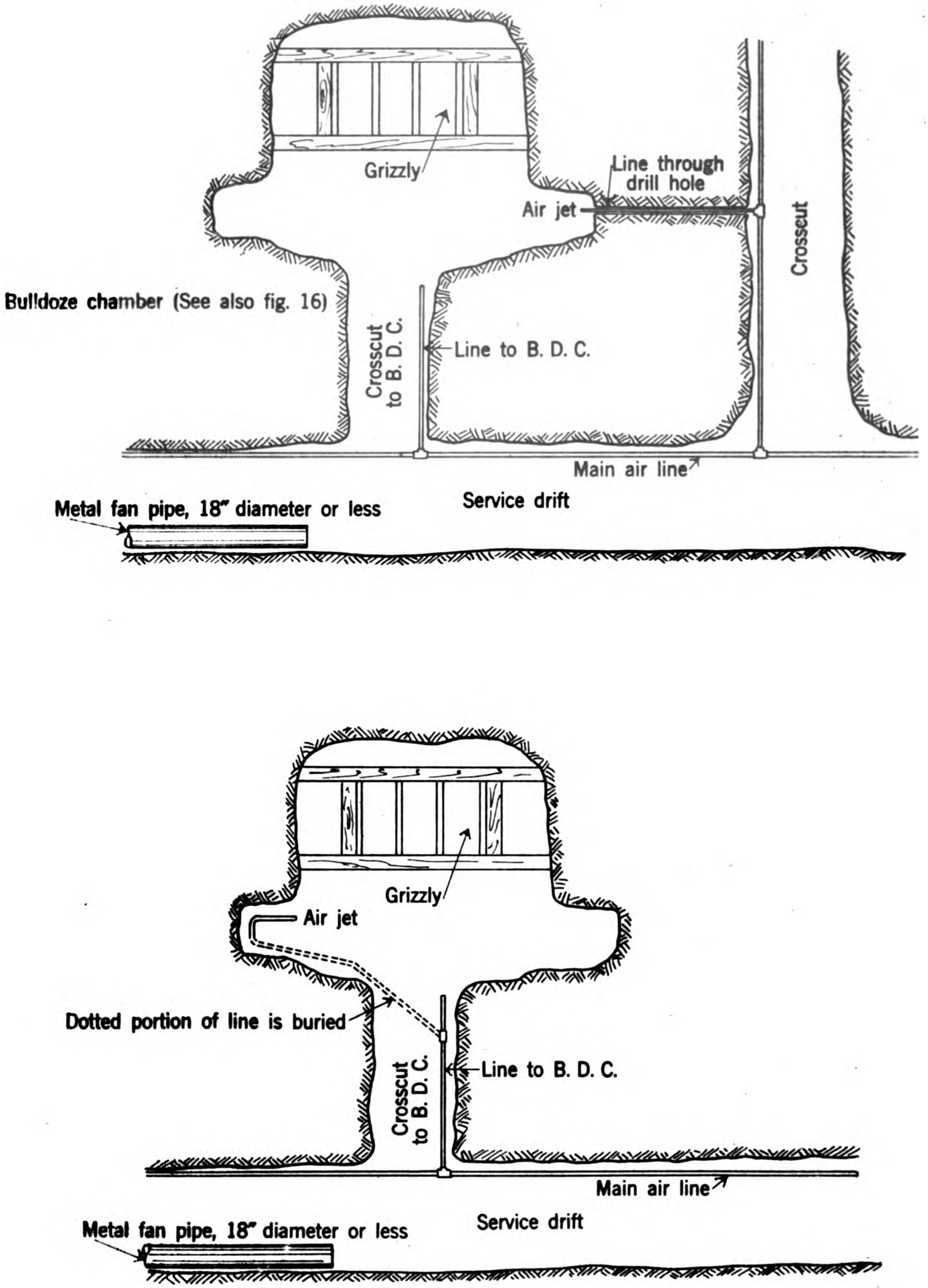


Figure 27.—Bulldoze-chamber ventilation.